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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXVII.—*On Galvanometers of High Sensibility;* by C. E. Mendenhall and C. W. Waidner.

After considerable experience with sensitive galvanometers we have been led to the design and construction of an instrument which, while it is not more sensitive than the best hitherto made, still possesses, we think, advantages as regards convenience and ease of manipulation which make this short account worth while. We also give the results of some experiments with minute magnets which have a bearing upon the general subject of sensitive galvanometry.

The galvanometer is of the ordinary four-coil Thomson type, the materials used being brass and glass, with insulating fiber supports for the coils. The dimensions are in general smaller than is customary, as can be seen from fig. 1, which shows a simplified elevation (details omitted), and which is drawn to scale, so that from the dimensions given a general idea of the proportions of the instrument can be obtained. It should be said that the tube for the quartz fiber is supported from the base independently of the outer cylindrical glass case, but the supporting pillars are omitted from the drawing for the sake of simplicity. Figure 2 shows a plan of the working arrangement of galvanometer, control magnet support, etc., while fig. 3 is a photograph of the instrument mounted for use, showing again the adjustments for control magnets, and the method of viewing the needle-system as it hangs in position.

The two pairs of coils are supported on two sliding carriages (suggested by the instrument of Mr. Abbot's design at the Smithsonian Astrophysical Observatory), but these can be given to-and-fro rectilinear motion by screws from outside the case. The coils have adjustments about vertical and horizontal axes, and vertical and horizontal sliding adjustments, so that they can be centered and placed parallel and vertical.

The glass tube carrying the quartz fiber passes through the top of the instrument nearly down to the top of the coils, and

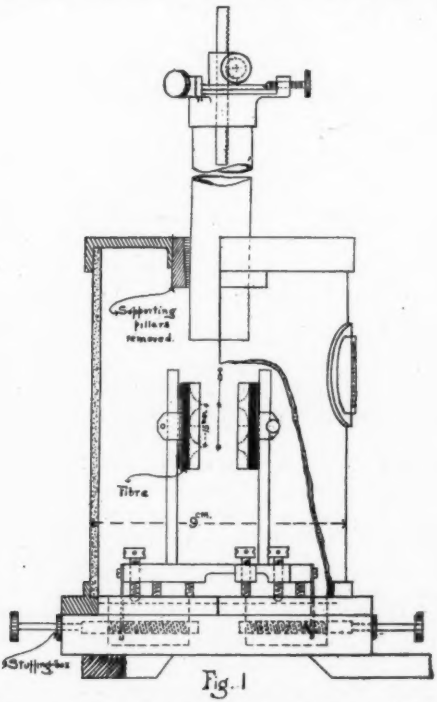


Fig. 1

carries at its upper end a rack and pinion motion for raising and lowering the fiber and system. By having the coil sup-

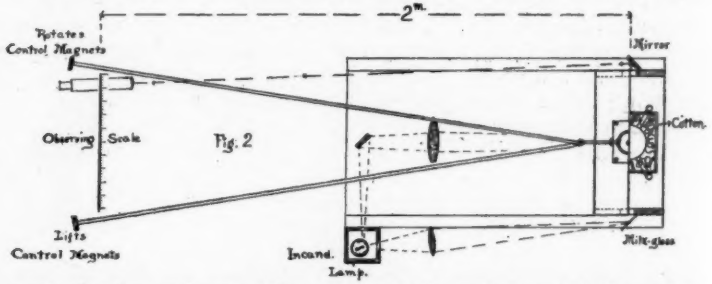


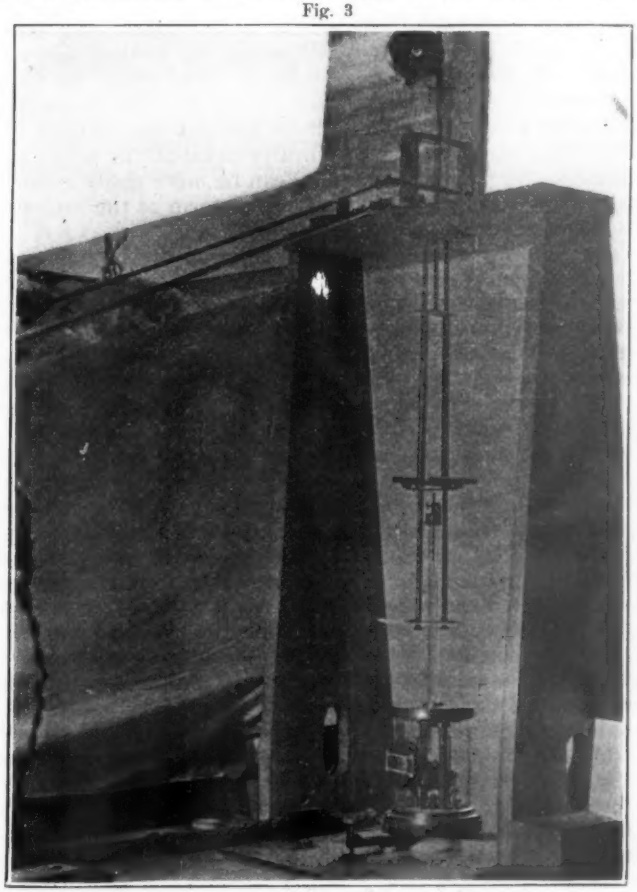
Fig. 2

ports slender and out of the way, and the outer case of glass, the space between the coils is well illuminated and easily visible.

The movable coils furnish a quick means of varying the sensibility; and besides, they render the insertion of light and

delicate systems a simple matter. The length of the quartz fiber is so chosen that the entire system can be drawn up into the glass tube; while in this position the tube can be placed in the galvanometer without danger to the fiber or system.

Fig. 3



The coils being now pulled apart, the system can be lowered into place, after which the coils can be approached as carefully as is desired. The easy visibility of the system is another important consideration; in particular we have found the arrangement of telescope, mirror and milk-glass screen, as shown in fig. 2 and fig. 3, extremely convenient, as enabling the operator at the scale to know the position of the system independent of the spot of light. The telescope is adjusted so

that the field of view includes the space between the coils, and shows the needle-system clearly defined against the illuminated milk-glass; when the system hangs in the desired position parallel to the coil-faces, the magnets appear end-on, and they are so thin that a very slight departure from this end-on position can be detected. In fact, "finding the spot of light" becomes easy; it can be adjusted to within a few centimeters of its desired position on the scale by adjusting the control magnets until the system-magnets appear end-on, after which the careful adjustment of zero can proceed as usual. The dimensions of the coils being small, very light systems can be used, the control field can be made very nearly equal at the upper and lower coils, and magnetic shielding can be more easily applied. Construction is simplified by the circular form of the case, permitting the extensive use of lathe work.

We would suggest the change of the top of the fiber tube from its present form to that given in fig. 1; the centering screws there shown would allow considerable horizontal adjustment of the fiber, and would clamp it in any desired position. A larger but shorter fiber tube—say 2^{cm} internal diameter, a heavier base, and a method of clamping the outer case above the base, so as to permit free access to the interior, would also be better.

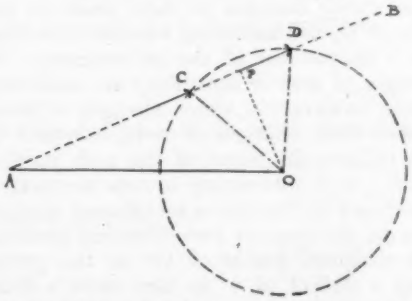
In connection with this instrument we have used a support for control magnets shown in plan in fig. 2, and in perspective in fig. 3; this permits an independent rotation and vertical motion of the symmetrical pair of control magnets, by the observer at the scale, using the long shafts shown in fig. 2. Independent changes in direction and magnitude of the control vector are thus possible.* In our apparatus, one turn of the observer's handle rotates the control magnets through 20°, and this is sufficiently delicate for most circumstances. It is convenient to have the magnetic force due to the control magnets nearly the same at the upper and lower coils, because the behavior of the needle can then be more easily predicted; with our control magnets 35^{cm} above the coils, there is a difference of about 15 per cent, which is ordinarily not enough to confuse matters. For example, if (fig. 4) AO represents in magnitude and direction the earth's magnetic force, AB the direction in which it is desired to have the resultant field, then for a given height of the control magnets there are two positions of the magnets, OC and OD, which give a resultant in the desired direction; one, OC, giving a long period of vibration, the other a short period. These two periods will be obtained provided the force OC due to the control magnets is greater than

*See Waidner, chap. on galvanometers, Ames & Bliss, Laboratory Manual; also, Rogers, in Nichols, "The Galvanometer."

OP and less than OA, and one of the periods increases and the other diminishes as OC approaches AO in magnitude.

Very light systems are of course extremely sensitive to air currents, such as will be produced by very slight inequalities in temperature; it is therefore important that the entire galvanometer be protected somewhat as indicated in fig. 2. The coil faces are covered with gold-leaf—and static charges of electricity upon them have given little or no trouble; but magnetic impurity in the material of the coils is very troublesome, and necessitates a free space of at least a millimeter between the coil faces (see Nichols, "The Galvanometer"). White silk insulation is somewhat better than green, though still very bad; and a part

Fig. 4



AO = Earth's Mag. Force.
OC, OD = Control Mag. Force.
AC, AD = Resultant Mag. Force.

of the difficulty is with the copper itself. The trouble seems to be in part due to a permanent magnetization of the coils, producing sometimes a rather complicated distribution of poles over the coil faces, which can be largely removed by a careful demagnetization of the coils; and in part to the poles induced by the approach of the magnets of the needle system itself—which can only be helped by using purer material.

In winding the coils the ends of all the sections were brought out, and small soldered junctions made on the back of the coil; hence six sizes of wire, viz.—40, 38, 36, 34, 32, 30, could be used without danger of wasting space in junctions. But the gain is probably hardly worth the trouble.

In making very light systems it is convenient to begin by fastening the magnets in the proper relative position, to a piece of plate glass with a solution of sugar or flour paste; after the glass staff and mirror have been fastened on, the system can be loosened with a drop of water. One of our best systems developed after use a second position of equilibrium, which it would assume if given a large deflection; it seemed to be due most probably to a change in strength of the magnets caused by the inductive action of the field, rather than to torsion of the staff of the system—as before suggested.*

* Astrophys. Journal, Jan., 1901, p. 47.

Changes of zero, and changes in sensibility.—In general both the zero and the sensibility of a galvanometer will be affected by the changes constantly going on in the direction and magnitude of the earth's horizontal force, and it becomes of interest to know whether there is any position of the galvanometer with respect to the magnetic meridian which will give minimum values for these disturbances. An examination of the magnetic records of the Naval Observatory shows that rather quick changes of H to the amount of nearly 1 per cent may be expected rarely, and to the amount of $\frac{1}{8}$ per cent frequently, while the declination sometimes changes rapidly by 19′ and frequently by 3′. A consideration of the vector diagram previously given, involving the earth's horizontal force H, the force due to the control magnet M, and the resultant force R, supposing the above changes to take place in the direction and magnitude of H, and assuming various directions for R, shows that there is no position of the galvanometer for which the resulting changes of zero or sensibility are markedly small. For null methods, however, in which changes of sensibility are of less moment than changes of zero, it would be somewhat advantageous to have the plane of the coils parallel to the magnetic meridian. It is interesting to note the magnitude of the changes produced by the above mentioned changes in H and the declination in the case of two identical systems, both arranged to have a complete period of 10^s in the galvanometer, but one having a period of 1^s in the earth's field, while the other is astaticised to a 4^s period. In the first case the resultant field in the galvanometer would equal $\frac{H}{100}$, in the second case $\frac{H}{6{\cdot}25}$; and we would have, if the plane of coils is perpendicular to magnetic meridian :—

(*a*) non-astatic,

change of zero due to 19′ change in declination,	= 0°
" " " " " " H of 1%	= 90°
change of sensibility due to 19′ change in declination	= 55%
" " " " " " H of 1%	= 50%

(*b*) astatic

change of zero due to 19′ change in declination	= 0°
" " " " " " H of 1%	= 3°40′
change of sensibility due to 19′ change in declination	= 3.5%
" " " " " " H of 1%	= $\frac{1}{2}$%

With the astatic system, but for the smaller changes in H and declination of $\frac{1}{8}$ per cent and 3′, the change in zero would be less than 30′ (or 18^{mm} at 1^m distance), and the change of sensibility about 0·6 per cent. This emphasizes the great importance of careful astaticising unless magnetic shielding is available.

Galvanometer Magnets.

The problem usually at hand in the construction of highly sensitive galvanometer systems is to construct a system which shall have the greatest attainable sensibility for a given period of vibration, as it is a great advantage to have a short working period, especially where magnetic disturbances cause constant variations in the zero. If we let

m_u = magnetic moment of the upper group of magnets,
m_l = magnetic moment of the lower group of magnets,
$M = m_u + m_l$
K = moment of inertia of the system (including also the non-magnetic material),
H = strength of the resultant controlling field,
T = time of a complete vibration (undamped),

then we have the following relations

$$T^2 = \frac{4\pi^2 K}{(m_u - m_l)H}$$

But the deflection for a given current and set of coils.

$$d \propto \frac{(m_u + m_l)}{H(m_u - m_l)}$$

or, substituting,

$$d \propto \frac{(m_u + m_l)T^2}{4\pi^2 K}$$

And for a given period this may be written

$$d \propto \frac{M}{K}$$

Consequently the greatest sensibility is attained by building up the system of such magnets that the relation $\frac{M}{K}$ shall be a maximum. It was with this object in view of determining the best dimensions of magnets, quality of steel, the mutual action of magnets on one another when placed near together as they are in galvanometer systems, the effect of boiling, and of mechanical jars, the magnetic moments and inductions attained in these short magnets, etc., that the experiments, recorded in the following tables, were made.

The magnetic moments of these small magnets were studied by mounting a number of them, as nearly alike as possible and whose dimensions had been carefully measured, on small brass discs whose moments of inertia would be accurately computed and were large in comparison with the moment of inertia of the magnets, which entered as a slight correction term. The

magnets were then magnetized in the uniform field of a small electromagnet and vibrated in an exhausted receiver placed at a point where the horizontal intensity of the earth's field had previously been determined. The slight controlling moment of the silk suspension was determined from the time of oscillation of the brass disc without any magnets on it, and allowed for in all the experiments. The results of these experiments are given in the following tables. These magnets were mounted on the face of the disc, side by side, so that they occupied the same relative positions that they would in a galvanometer system.

Designation of Magnet.	Quality of Steel.	Length mm.	Width mm.	Thickness mm.	Volume per Magnet ccm.	Weight per Magnet grms.	Magnetizing Field. C. G. S. Lines.	Magnetic Moment per Magnet.	I Av'ge Intens. of Magnetization.
H_1	Fine Watch Spring	5·30	0·170	0·061	0·000055	0·00043	3400	0·02580	469
H_2	"	4·15	0·172	0·060	0·000043	0·000337	"	0·0184	422
H_3	"	3·16	0·174	0·059	0·000032	0·000251	"	0·0122	382
H_4	"	1·95	0·175	0·058	0·0000197	0·000155	"	0·00485	246
H_5	"	1·24	0·175	0·059	0·0000128	0·000100	"	0·00215	168
H_6	"	1·02	0·173	0·059	0·0000103	0·000081	"	0·00143	139
H_7	"	0·650	0·170	0·061	0·0000067	0·000053	"	0·000542	81
G_1	"	3·00	0·197	0·050	0·0000295	0·000232	"	0·0110	372
G_2	"	1·81	0·197	0·050	0·0000178	0·000140	"	0·00405	228
G_3	"	0·98	0·210	0·050	0·0000103	0·000081	"	0·00130	127
I_1	J. and C. Spec. Mag. Steel.	1·12	0·252	0·050	0·0000141	0·000111	"	0·00252	179
I_2	"	1·15	0·161	0·052	0·0000096	0·000076	"	0·00193	201
B_1	"	4·12	0·89	0·120	0·00044	0·00345	2200	0·1251	284
"							5200	0·1248	283
B_2	"	1·53	0·79	0·126	0·000152	0·00119	800	0·0102	67
"							1300	0·0107	70·5
"							3400	0·0107	70·5
B_3		1·09	0·74	0·125	0·000101	0·00079	"	0·0052	51
A_1	Watch Spring	3·35	0·52	0·115	0·000200	0·00157	3400	0·0407	202
A_2	"	2·29	0·51	0·115	0·000135	0·00105	"	0·0198	144
A_3	"	1·67	0·52	0·115	0·000100	0·00078	"	0·0100	99
A_4	"	0·80	0·50	0·115	0·000046	0·000361	"	0·0031	67
A_5	"	1·53	0·254	0·114	0·000044	0·000345	"	0·0049	111
C_1	Boker's Music Wire	3·13	D=	0·22	0·000119	0·00094	"	0·0211	177
C_2		1·14	D=	0·22	0·000043	0·00034	"	0·0024	55
J_1	Extra fine Steel	2·20	D=	0·078	0·0000105	0·000082	"	0·00284	270
J_2		1·21	D=	0·069	0·0000045	0·000035	"	0·00076	168

Saturation of Magnets.—The experiments with magnet B_1 (see preceding table), magnetized in fields of 2200 and 5200 lines, and with magnet B_2, magnetized in fields varying from 800 to 3400 lines per sq. cm., show that a limit to the intensity of magnetization attainable is soon reached, practically in a field of 1000 lines of induction per cm². We undoubtedly have the isthmus effect coming in when these small magnets are magnetized by placing them between the faces of an electromagnet; thus in B, which was magnetized in a field (undisturbed) of 2200, an average intensity of magnetization of 284 is reached, which must correspond to an average remanent induction of at least 3500.

Effect of Length and Cross Section of Magnets.—The experiments made on the group of fine hair-spring magnets H_1 to H_{11}, all taken from one piece tempered glass hard in water, shows the variation of the magnetic moment with the length. These results are plotted in a curve, fig. 6 (p. 260), which shows that, for short magnets, the magnetic moment decreases much more rapidly than in proportion to the length.

The effect of cross section on the intensity of magnetization is shown by comparing, e. g., H_6 and B_2, the average intensity of magnetization in H_6 (although shorter) being more than 2·7 times that in B_2. Similarily A_5 (width reduced by grinding), although shorter, has a considerably greater intensity of magnetization than A_2. This strongly emphasizes the fact that probably the greatest gain in sensibility at present at our disposal is in the use of a number of magnets of small cross section instead of one (or so) of large section, i. e., if you have a given mass of magnetic material (to be made up of magnets of a given length), the system will be considerably more sensitive if you use a number of magnets of small cross section. This brings up at once the question whether, when you divide up the magnetic material into a number of thin magnets, you do not in the end lose what you gained in magnetic moment by subdivision, by the fact that in galvanometer systems the magnets must be placed very near together and so tend by their mutual action to weaken one another.

Mutual Action of Magnets.—This question was investigated for many sizes of magnets and under various conditions; one or two experiments will, however, be sufficient to show that the effect is much smaller than is usually supposed. To study this the magnets B_1 were fastened to one of the brass inertia discs, magnetized, and period determined, in an exhausted receiver, when the distance between the centers of the magnets was 3·3^{mm}; the magnets were then pushed together until the distance between the centers of the magnets was 1·2^{mm}, when the

period was again determined; magnets then pushed apart, etc. The results are shown in the following table:

Distance between Centers of Magnets.	T Time of Vibration of Disc.	M Magnetic Moment C. G. S. Units.
3·2^{mm}	2·618^{secs}	0·1251
1·2	2·718	·1160
3·2	2·659	·1212
1·2	2·725	·1155
3·2	2·663	·1209
1·2	2·727	·1153
3·2	2·666	·1206

These experiments show that the first near approach of the magnets produced a permanent decrease in the magnetic moment amounting to about 4 per cent (this was to be expected inasmuch as these magnets had not been aged). After that it will be seen that the magnets practically regain their former magnetic moment on separation. The temporary decrease in magnetic moment due to mutual action is less than 5 per cent.

A similar set of experiments with the shorter magnets, $B_,$ gave a decrease of 5·5 per cent due to mutual action when the center lines of the magnets were 1^{mm} apart. When the magnets were pushed together so that they touched their neighbors throughout their length, the magnetic moment continued to decrease for some minutes until the decrease amounted to 19 per cent, and on separating them they did not recover but were permanently weakened about 10 per cent.

Quality of Steel.—Under similar conditions magnets of Jonas & Colver's special magnet steel* (probably tungsten steel) have moments about 25 per cent greater than those made from watch hair-spring, which is the next best material.

Effect of Jars, etc.—Magnets $B_,$ 4^{mm} long, dropped twenty times though 30^{cm} on to a glass plate diminished only $\frac{1}{5}$ per cent in magnetic moment; with magnets B^3, 1^{mm} long, the change was less than 1 per cent. Boiling immediately after magnetization reduces the moment by 10 per cent or 15 per cent, and most of the loss occurs during the first few minutes of boiling.

Paschen† has called attention to the fact that to increase the sensibility, for a given period, we must increase the total magnetic moment M and decrease the moment of inertia, K. Assuming that the magnetic moment is proportional to the volume, i. e., for a given cross section proportional to the length of the magnet, and that the inertia of the non-magnetic

* From Boker & Co., N. Y. † Wied. Ann., xlviii, 282.

material could be neglected, Paschen showed that if two systems were made with magnets of the same cross section but of lengths l and $\frac{l}{n}$ respectively, then the second should give a deflection n^2 times as large as the first system, for if

the magnetic moment of the first system $= M_1$
and the moment of inertia " " " $= K_1$

then

the magnetic moment of the second system $= \frac{M_1}{n}$

and the mom. of inertia " " " $= \frac{K_1}{n^2}$

The deflection of first system is proportional to $\frac{M_1}{K_1}$

and " " " second " proportional to $\frac{M_1}{n} \Big/ \frac{K_1}{n^2}$

i. e., the deflection of the second system is n^2 times that of the first system. The assumption (that $M \propto l$ for given cross section) on which the deduction is based is not even approximately true for short magnets, as the preceding experiments show, but it does at least indicate an advantage in favor of short magnets. This deduction is supported by experiment. Thus Paschen found by testing three similar systems having magnets 4^{mm}, 2^{mm}, and $1{\cdot}3^{mm}$ long respectively, made from the same fine hair-spring, that the second gave three times the deflection and the third six times the deflection of the first system.

From curve 1 it will be seen that, if the moment of inertia of the non-magnetic parts of the system can be neglected in comparison with that of the magnetic (a condition which can perhaps be realized even with systems as light as 2 mg. total weight) the sensibilities of two systems having magnets 2^{mm} and 1^{mm} long respectively, of the same material and cross section, would be proportional to

$$\frac{M_1}{K_1} = \frac{5{\cdot}2}{(2)^3} \quad \text{for system 1}$$

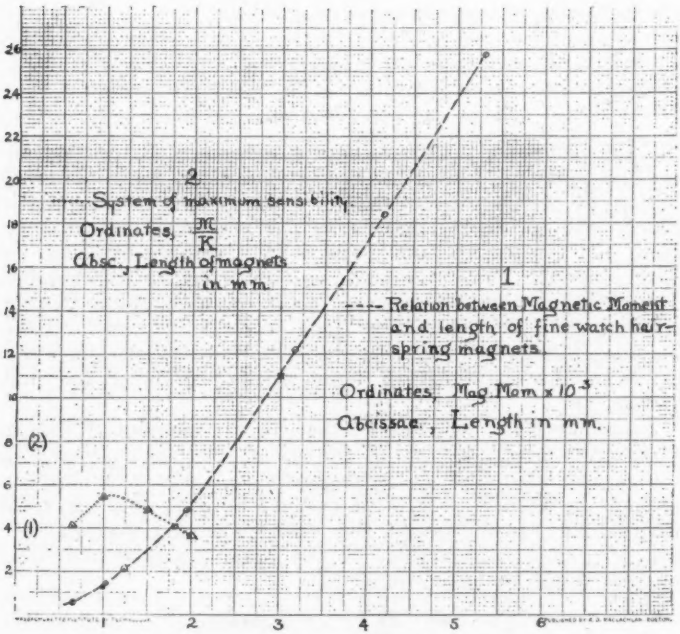
$$\frac{M_2}{K_2} = \frac{1{\cdot}38}{(1)^3} \quad \text{for system 2}$$

i. e. the second system would be about twice as sensitive as the first, instead of four times as deduced by Paschen on the assumption that $M \propto l$ for given cross section.

If it were always possible to use enough magnets, so that the non-magnetic moment of inertia could be neglected, then the

sensibility would continue to increase as the magnets decreased in length. This not being the case in general, it is possible to use too short magnets. To show this we have calculated the sensibilities to be expected with four systems made of the same material and cross section as magnets I_2 (see table), which showed a greater intensity of magnetization than any others of the same length. Furthermore we assumed that only four such magnets were to be used in each group, to be ·65^{mm} long in the first system, and 1^{mm}, 1·5^{mm}, 2^{mm} in the others; that the mirror weighed ·23 mg., and was 1^{mm} x 1·1^{mm} in area, the staff

Fig. 5



and shellac weighed ·09 mg., and the hook ·06 mg.—these values being found by trial. Except for the omission of the hook, which is readily dispensed with, it would be difficult to reduce the non-magnetic mass much below this. The results are shown in curve 2—where ordinates are proportional to sensibility, and abscissæ to length of magnets used. A very decided maximum is shown, for a length of 1·1^{mm}. It must be said, however, that the magnets could be put closer together without undue demagnetization, and that two sets could be

mounted, one on each side of the staff, thus increasing the number from eight to twenty; this would require shorter magnets for maximum sensibility.

We have not yet exactly realized this system in practice, but give the result obtained with a system having only six magnets, of the same material and cross section as I_2, and an average length of about $1{\cdot}16^{mm}$; the non-magnetic moment of inertia was probably a little less than that assumed in the above calculation. The sensibility actually obtained, and also the sensibility reduced to the Ayrton–Mather scale, is given in the following table, together with the sensibilities of a few other recent galvanometers, taken from the table of Ayrton and Mather (Phil. Mag., Oct., 1898).

It should be noted that with these very light systems the "period" when it is at all long—say 5^s to 10^s complete—is very difficult to determine, on account of the great damping. Moreover, it is unfair to compare systems which were tested at considerably different periods, and reduced to the same period by assuming the sensibility $\propto T^2$—for this is on the basis of a *free* period.* In computing moments of inertia for the above systems, we have assumed that the axis of rotation passed through the center of gravity of the system and was parallel to the staff; if the system is badly constructed so that the axis of rotation departs $\cdot 2^{mm}$ from the staff at its upper extremity, the moment of inertia will of course be increased, and the sensibility (for a given period) decreased by about 25 per cent. The moments of inertia of the four systems computed for use in plotting curve 2 varied between 44×10^{-5} and 529×10^{-5} C. G. S. units.

TABLE.

Galvanometer and Constants when tested.	Suspension System.	Sensibility and conditions of use when tested.	Deflections per micro-ampere when scale dist.=1000 scale divs., complete period = 10 secs. Resistance =1 ohm.
Snow (Wied. Ann. xlvii, p. 218; Phys. Rev., i, p. 37). 4 coils, 30mm. ext. and 6mm. int. diam. Each coil wound in 2 sections, with 1800 turns. $R = 140$ *ohms* (series)	6 small watch-spring magnets in each group. 3 on each side of staff. Magnets 3–4 mm. long. Mirror 5 mm. dia., 0·14mm. thick. Quartz fibre 40cm. long. Wt. of system = 80mg.	$C = 1{\cdot}5 \times 10^{-11}$ *amp. per mm.* Scale dist. = 300cm. T (complete) = 10 secs. R = 140 ohms.	470

* See Ayrton and Mather, Phil. Mag., pp. 366, 1898.

Galvanometer and Constants when tested.	Suspension System.	Sensibility and conditions of use when tested.	Deflections per micro-ampere when scale dist.=1000 scale divs. complete period = 10 secs. Resistance =1 ohm.
Wadsworth (Phil. Mag., xxxviii, p. 553). 4 coils, 50mm. ext. diam., 2mm. int. and 40mm. deep. Each coil wound in 5 sections, with 2396 turns. R=86 *ohms* (series)	10 small magnets in each group (5 on each side of staff, varying from 2–3mm. in length) made from smallest size sewing needles (untreated). Glass 150 mm. long, weighs 5mg. Mirror (concave) 2·5mm. diam. and weighs 12mg.	$C = 4 \times 10^{-11}$ *amp. per mm.* Scale dist. = 100cm. T (complete) = 20 secs. R=86 ohms.	675
Nichols E. L. and E. F. (Phys. Rev., i, p. 2). R=9·3 *ohms* (parallel)	Wt. of system = 48mg.	$C = 1{\cdot}3 \times 10^{-10}$ *amp. per mm.* Scale dist = 150cm. T (complete) = 10 secs. R=9·3 ohms.	2200
Paschen Wied. Ann., xlviii, p. 284). 4 coils, 40mm. external and 5mm. internal diam. Wound with graded wire, about 1200 turns in each coil. R=60 *ohms.*	Each group has 13 magnets 1 to 1·5 mm. long, on both sides of glass staff 0·3mm. apart; Mirror 2mm. dia. 0·03mm. thick. 5cm. quartz fibre. Wt. of system = 5mg.	$C = 3{\cdot}3 \times 10^{-12}$ *amp. per mm.* Scale dist. = 300cm. T = 15 secs. (aperiodic, i. e, has only one turning point). R=60 ohms.	5800
Mendenhall and Waidner. 4 coils, ext. diam. =15mm., internal diam. = 2 mm. 6 sizes of wire, 500 turns on each coil. R=3 *ohms* (in parallel)	3 magnets in each group. Total wt. 1mg. Wt. of magnetic part of needle = ·68mg.; length of magnets =1·15mm. Plane mirror, ·9mm. × 1mm.	$C = 5{\cdot}6 \times 10^{-11}$ amp. per mm. deflection. Scale dist. =200cm. T=9 sec. complete aperiodic (i. e. has only one turning point). Zero stable. R=3 ohms.	6090

Thompson Physical Laboratory,
Williams College.

ART. XXVIII.—*On a Method of Locating Nodes and Loops of Sound in the Open Air with Applications;* by BERGEN DAVIS, PH.D.

THE experiments and determinations given in this article constitute an application of a new phenomenon recently described by the writer in this Journal.* It is now my wish to point out how the device previously described can be used to locate nodes and loops of sound waves outside of organ-pipes, and in general how the mechanical effects produced by sound waves, at a distance from this source, can be studied.

It having been found that a small hollow cylinder which is closed at one end, will move across a stationary sound-wave in a direction perpendicular to the stream-lines, a small mill-like arrangement was constructed by placing four hollow cylinders on the ends of card-board arms, in such a manner that the closed ends pointed in the same angular direction. This mill was provided with a glass pivot at its center, and was supported on the point of a fine needle.

The cylinders were made from No. 00 gelatine capsules, and were each 1·7^{cm} long and ·79^{cm} in diameter. This system was mounted in the mouth of a resonator, with the plane of the system parallel to the mouth, and hence perpendicular to the direction of vibration. The aperture of the resonator, with the mill in place, is shown in figure 1. The resonator was in unison with an organ-pipe of considerable power, and when the pipe was blown the mill was found to rotate with a high velocity, and the rate of rotation was different for different positions in the room. By carrying the resonator around a large room, the positions of the nodes and loops could be located with considerable accuracy.

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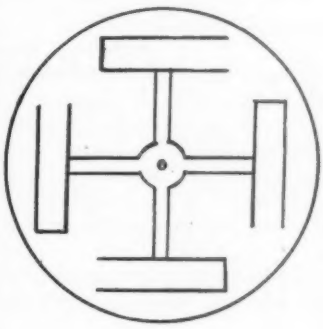


The resonator containing the mill was next carried to another large room, on the floor above that where the pipe was located: there was no opening in the floor or ceiling between the rooms, and the doors of both rooms were tightly closed, but in spite of this, the mill was observed to rotate as before, but not so rapidly. Nodes and loops could be located here also.

* Bergen Davis, this Journal, Sept., 1901, p. 185.

In order to avoid reflection from walls, and the consequent formation of stationary waves, the pipe was then carried out of doors, and compressed air led to it by a long rubber pipe. Here, in the open air, the mill was found to rotate very rapidly when near the pipe, and the rate decreased with the distance from the pipe, ceasing to rotate at about 60 feet from the pipe. This distance could probably be very much increased by the use of more delicate apparatus, especial care being taken with the pivot and needle point. This furnishes a means of studying the decrease of intensity with distance, and, with the aid of the formula developed by Lord Rayleigh,* of measuring the actual amplitude of the vibration at various points in the open air.

A very sensitive sound detector of this character might be made by suspending a system of very small cylinders in the mouth of the resonator by means of a quartz fiber, and then observing the deflection by a mirror and telescope. Such an instrument ought to be as sensitive as the one constructed by Boys, who used a suspended disc for the same purpose.† An instrument of this kind, perhaps, might be useful in investigating the acoustic properties of buildings, also in the study of the reflection, refraction and absorption of sound.

Physical Laboratory, Columbia University,
June 15, 1901.

* Theory of Sound, II, pp. 195–200.
† Boys, Nature, vol. xlii, p. 604.

ART. XXIX.—*The Anatomy of the Fruit of Cocos nucifera*;* by A. L. WINTON.

[Contribution from The Connecticut Agricultural Experiment Station, New Haven, Conn.]

I. MORPHOLOGY AND MACROSCOPIC STRUCTURE.

SINCE the general structure of the cocoanut fruit has been treated by numerous writers on systematic and economic botany, only such facts are here given as are essential for a clear understanding of the relation of the parts and the microscopic structure.

The flowers are arranged in spikes branching from a central axis and inclosed with a tough spathe usually a meter or more in length (fig. 1). A single female flower is borne near the base of each lateral axis, and numerous male flowers are distributed on all sides of the axis between the female flower and the apex. After the male flowers drop, each naked lateral axis persists and is a prominent appendage of the fruit (figs. 2 and 3, *S*). Only one ovule of the three-celled ovary comes to maturity, but the tricarpelary nature of the fruit is indicated by its triangular shape as well as by the longitudinal ridges and the three eyes or germinating hole of the nut.

The epicarp of the fruit (fig. 3, *Epi*) is a smooth tough coat, of a brownish or grayish color.

The mesocarp (fig. 3, *Mes*), consists of a hard outer coat but a few mm. thick and a soft portion usually 3–4^{cm} thick on the sides and much thicker on the base. Imbedded in the mesocarp are numerous longitudinally arranged fibers, varying in size from slender hairs to large, sparingly branching and anastomosing, flattened forms, 2–3^{mm} broad. The large fibers are situated chiefly in the inner layers, with their flat surfaces parallel with the surface of the nut.

Oftentimes the inner layers of the mesocarp become impregnated with a brown fluid, which on drying, gives the thin tissue a mottled brown appearance.

* European microscopists have studied the foods and adulterants which have come under their observation but have overlooked a number of distinctly American products. The writer has undertaken to fill in some of these gaps by a series of papers, of which this is the second. The first paper, on the anatomy of maize cob, was published in the Oesterreichische Chemiker-Zeitung, 1900, p. 345, and also in the Conn. Experiment Station Report, 1900, p. 186.

Each paper will describe from the purely scientific standpoint the macroscopic and histological structure of the material investigated, and also in a final chapter point out the application of this knowledge to the detection of adulteration. The last chapter is not strictly suited to the pages of this Journal, but is so dependent on the scientific descriptions which precede it that it would be almost valueless if published separately.

FIG. 1. Inflorescence of the cocoanut showing spathe inclosing the spikes, each with numerous male flowers above and a single female flower near the base. × ⅛.

FIG. 2. Half grown cocoanut fruit with calyx, and axis from which the male flowers have fallen. × ¼.

FIG. 4. Inner surface of a cocoanut shell with adhering outer testa. At the left the raphe, from which proceed veins forming a network over the surface. × ¼.

The endocarp, or shell (fig. 3, *End*), consists of a hard, dark brown coat, 2–6^{mm} thick, with numerous fibers adhering to the surface. Three nearly equidistant ridges (often indistinct) pass from base to apex, where they unite to form a blunt point. At the basal end, between the ridges, are the three depressions or eyes, the tissues of which are much softer and thinner than of the rest of the shell (fig. 3, *K*). Through the softest of these eyes the embryo, embedded in the endosperm directly behind it, escapes in sprouting.

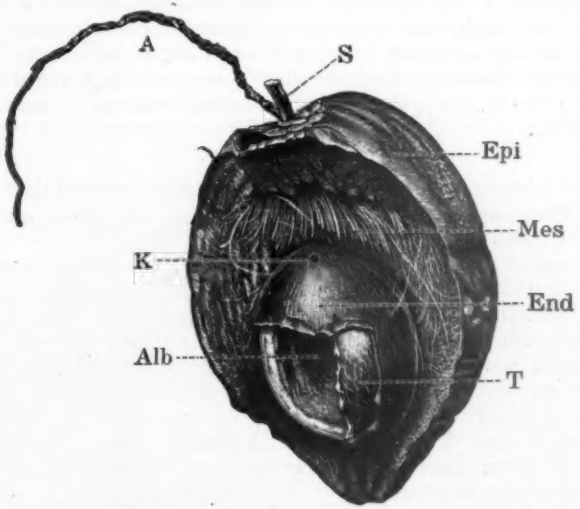


FIG. 3. Ripe cocoanut fruit. *S*, lower part of axis forming the stem; *A*, upper end of axis with scars of male flowers; *Epi*, epicarp; *Mes*, mesocarp with fibers; *End*, endocarp or hard shell; *T*, portion of testa adhering to endosperm; *Alb*, endosperm surrounding cavity of the nut; *K*, germinating eye. × ⅓.

The testa of the anatropous seed (fig. 3, *T*, and fig. 4) is a thin coat of a light brown color, closely united with the endocarp without and the endosperm within. Embedded in the outer portion and extending from the principal eye nearly to the apex is the raphe, consisting of a thin band of vascular tissues about 1^{cm} broad, which sends off branches in all directions, forming a network about the seed. The endosperm with the inner portion of the testa may be separated from the outer testa and endocarp by introducing a knife blade between the layers. By this operation the veins are split, part of the vascular tissue adhering to the convex surface of the inner testa, and the remainder to the concave surface of the outer testa, so that both surfaces are covered with reticulations.

The endosperm or meat of the cocoanut (fig. 3, *Alb.*) is a white, fleshy layer, 1–2^{cm} thick, in which, near the base, is embedded the small embryo. While immature, the nut is filled with a milky liquid and has no solid endosperm, but as the ripening proceeds the endosperm is gradually formed and at the same time the milky liquid diminishes in quantity or entirely disappears.

Cocoanuts yield food for man and cattle, oil, fiber, and other useful products. The epicarp and mesocarp are cut away from nuts designed for export, although invariably a small amount of the mesocarp with its fibers remains attached to the shell. In removing the meat, the outer testa, as has been stated, also adheres to the hard shell, so that cocoanut shells consist not merely of endocarp, but also of a certain amount of mesocarp and testa.

II. Histology.

The microscopic structure of the cocoanut seed is described by Hanausek,* Harz,† Moeller,‡ Koenig§ and other authorities on foods and applied microscopy.

Cocoanut fiber (coir), which has long been extensively employed in making mats and cordage, and also cocoanut shell, which has been used for making knobs and other turned articles, were studied by Wiesner‖ nearly thirty years ago, but his work was designed chiefly to distinguish the fiber from other commercial fibers and the shell from the similar shell of *Attalea funifera.*

Von Hoehnel¶ describes briefly the histology of coir, but, like Wiesner, does not appear to have understood the true nature of the stegmata.

Weiss,** Engler and Prantl,†† and some other authors refer briefly to the microscopic structure of parts of the cocoanut, but their descriptions are of little value in diagnosis.

1. *Epicarp.*

The epicarp or epidermal layer is about ·015^{mm} thick and is made up of tabular cells with dark brown contents. In surface view the cells are usually square, rectangular or tri-

* Die Nahrungs- und Genussmittel aus dem Pflanzenreiche, Kassel, 1884, p. 155.

† Landwirthschaftliche Samenkunde, Berlin, 1885, p. 1120.

‡ Mikroscopie der Nahrungs- und Genussmittel aus dem Pflanzenreiche, Berlin, 1886, p. 241.

§ Die Untersuchung landwirtschaftlich u. gewerblich wichtiger Stoffe, Berlin, 1898, p. 291.

‖ Die Rohstoffe des Pflanzen-Reiches, Leipzig, 1873, pp. 436 and 789. (A new edition is being published in parts, but the chapters on the cocoanut have not yet appeared.)

¶ Die Microscopie der technisch verwendeten Faserstoffe, Leipzig, 1887, p. 52.

** Anatomie der Pflanzen, Wien, 1878, 1 Band.

†† Die natürlichen Pflanzenfamilien, II Theil, 3 Abteilung, p. 22.

angular, with double walls about ·005^{mm} thick and are arranged with some regularity in rows.

2. *Mesocarp.*

(a) *Hard ground tissue.*—This tissue consists of thick-walled cells which are often tangentially-transversely elongated. In the first few layers the walls are about the same thickness as in the epidermis, without evident pores, but further inward they are more strongly thickened (double walls often ·015^{mm} thick) and conspicuously porous. Still further inward they pass into the parenchyma of the soft ground tissue.

(b) *Bast-fiber bundles.*—In the hard ground tissue the bundles have no phloem or xylem but are composed entirely of bast-fibers with cell walls often thicker than the lumen. The number of fibers seen in cross section varies from two or three

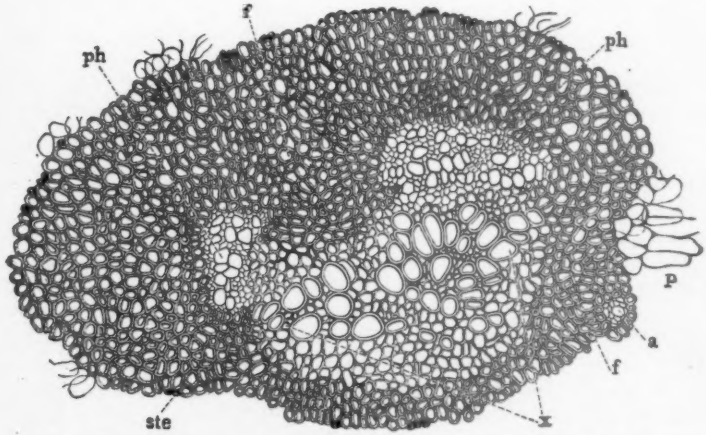


FIG. 5. Transverse section of a large flattened (mesocarp) fiber of the cocoanut. *ste*, stegmata; *f*, sheath of bast fibers; *ph*, two phloem groups; *x*, xylem; *p*, parenchyma of ground tissue; *a*, rudimentary bundle belonging to small branch. × 90.

up to a hundred or more. Transitional forms between fibrous and fibro-vascular bundles occur further inward.

(c) *Soft ground tissue.*—The thin-walled parenchyma cells of the soft ground tissue are in some parts isodiametric, in other parts longitudinally elongated, and in still other parts transversely-tangentially elongated (fig. 8, *w*). Wherever the brown liquid previously referred to has penetrated the inner layers of the mesocarp, groups of the parenchyma cells here and there, being impregnated with this material, are of a rich brown color and appear thicker-walled than the others (fig. 8,

br.). This brown substance is quickly changed to a reddish color by caustic potash, but is not affected by alcohol, ether or the specific reagents for proteids, fats and resins. No immediate effect is produced by ferric chloride solution, but on long standing the color is changed to olive green.

(d) *Fibers* (*Coir*).—These are fibro-vascular bundles with a strongly developed sheath of bast-fibers. Toward the xylem side of the bundle, particularly in the large fibers, the sheath usually diminishes in thickness and the vascular portion, as seen in cross section, is more or less eccentric, surrounded by a crescent-shaped sheath with the horns connected by a narrower strip.

In the smaller fibers there is but one group of phloem elements, but in the larger flattened fibers there are usually two, or occasionally more, groups separated from each other by a continuation of the sheath (fig. 5). Normally the xylem is near the inner flat side and the two phloem groups are approximately symmetrical with reference to the shorter axis of the elliptical cross section; but often the xylem is near one of the narrow sides and the phloem groups are symmetrical with reference to the longer axis, and still more often the arrangement is diagonal or otherwise irregular.

Mohl* in 1831 noted that the phloem in the stem of *Calamus* was normally divided into two distinct groups, and Kny† as well as other authors have since found the same arrangement in a number of palms. By the study of many sections, the writer has demonstrated that a cocoanut fiber with two phloem groups has also a double xylem, although in most sections no separation is evident, and the whole fiber consists of two simple bundles united side by side, which may completely separate further on in their course by the forking of the fiber.

Serial sections cut through such compound fibers show that at the place of forking the phloem groups are still further separated and the xylem also is divided by bast-fibers, thus forming two distinct bundles which pass into the two branches. The phloem in each branch is at first entire, but further on, if the branch is large it usually divides, and still further on the whole bundle may split up, with the formation again of two fibers. Occasionally a fiber which has no evident division of the xylem has four groups indicating that the fiber is composed of four united bundles, which, on branching, form two fibers each with a double bundle.

Large fibers not only fork but also send off small lateral branches. The rudimentary bundles belonging to such

* De Palmarum Structura, Translation in Ray. Soc. Reports and Papers, 1849, p. 29.

† Verhandl. d. Bot. Ver. Prov. Brandenburg, Bd. xxiii, 1881, pp. 94–109.

branches may often be seen in cross sections of the trunk fiber below the place of branching (fig. 5, *a*).

a. Stegmata (figs. 5 and 6, *ste*).—As seen in surface view these are circular or elliptical cells from ·008 to ·020^{mm} in diameter, which extend in longitudinal rows over the surface of the fibers. Longitudinal sections show that the cells are biconvex, fitting into depressions in the bast-fibers, and that the outer walls are exceedingly thin, while the inner and side walls are strongly thickened, thus bringing the cell cavity near the outer surface. Inclosed in each cell and filling it almost completely, is a silicious body, from ·006 to ·012^{mm} in diameter, with wart-like protuberances on the surface which fit into corresponding depressions in the cell walls (fig. 7). That they are composed

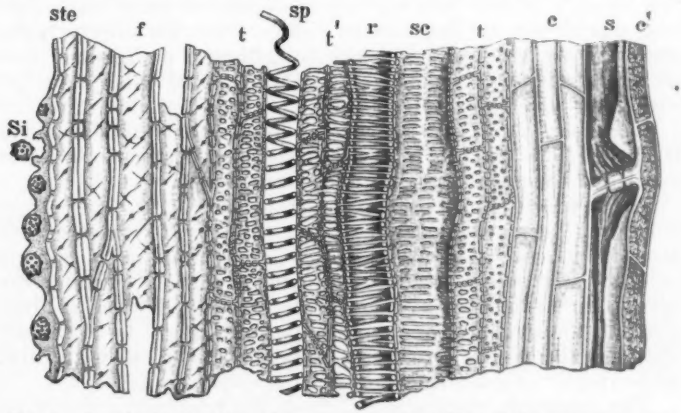


FIG. 6. Longitudinal section of a large (mesocarp) fiber of the cocoanut. *ste*, stegmata; *Si*, silicious body; *f*, bast fibers; *t*, tracheids with small pits; *t'*, tracheids with large pits; *sp*, spiral trachea; *r*, reticulated trachea; *sc*, scalariform trachea; *s*, sieve tube; *c* and *c'*, cambiform cells. × 300.

of silica is demonstrated by their incombustibility, their insolubility in hydrochloric and nitric acids and their complete solubility in hydrofluoric acid. Their appearance is particularly striking in tangential sections which have been heated on a cover glass until thoroughly carbonized and finally treated with hydrochloric acid on the slide. The heating should be performed at dull redness, since at a higher temperature the bodies lose their characteristic appearance.

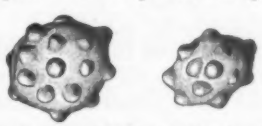


FIG. 7. Silicious bodies from the stegmata of cocoanut fiber. × 1500.

Wiesner* refers to these stegmata as "bast parenchyma," and from his description it would appear that he considered them

* Loc. cit, pp. 436–438.

silicified cells and did not understand that they are *sclerenchymatized cells* with *silicious contents.* Von Hoehnel,* who uses, however, the term "stegmata," also appears to have fallen into the same error.

Rosanoff† found stegmata in twelve species of palms, and Kohl,‡ who has made an exhaustive study of the subject, in twenty-three additional species. Neither author mentions *Cocos nucifera*, but Kohl found in *C. flexuosa* stegamata with silicious contents which answer the description of those in coir fiber.

β. Bast-fibers (figs. 5 and 6, *f*) completely surround the bundle. They vary in length up to 2^{mm} and in diameter up to ·03^{mm}. The double cell walls are from one-half to one-sixth the breadth of the lumina, with conspicuous pores and diagonal markings. In longitudinal section the walls adjoining the stegmata are sinuous in outline, due to the depressions into which the stegmata are fitted. On the edge of the xylem the bast-fibers pass into tracheids (fig. 6, *t*).

γ. Xylem (fig. 5, *x*; fig. 6). The elements are tracheæ, tracheids and various forms intermediate between tracheids and bast-fibers, and tracheids and parenchyma.

The tracheæ range in diameter up to ·05^{mm}, the larger (found in large fibers) being reticulated (fig. 6, *r*) or scalariform-reticulated (*sc*), the smaller (found both in large and small fibers) being spiral or reticulated spiral. Among the spiral tracheæ one finds considerable variation both as to their size and the steepness of their spirals. As might be expected, those in the protoxylem often have delicate spirals with turns wide apart. An intermediate form is shown in fig. 6 (*sp*).

The tracheids, distinguished from the tracheæ by the transverse or diagonal partitions and by their smaller size and thinner walls, likewise display an interesting diversity of size and form. Among these are forms with large pits and curious reticulations (fig. 6, *t'*), also transitional forms between tracheids and bast-fibers (*t*) on the one hand, and tracheids and parenchyma on the other.

δ Phloem. Sieve tubes and cambiform cells make up the phloem (fig. 5, *ph*).

Measured in cross sections, the diameters of the sieve tubes vary up to ·03^{mm}. In longitudinal sections it may be seen that the sieve plates are either at right angles to the walls or oblique and that oftentimes they are covered with callus through which run a few indistinct pores (fig. 6, *s*).

* Loc. cit., p. 52.
† Bot. Ztg., 1871, p. 749.
‡ Kalksalze und Kieselsäure in der Pflanze, Marburg, 1889, p. 289.

Cambiform cells occur singly, in rows and in groups among the sieve tubes and also at the edges of the phloem. Those among the sieve tubes are for the most part small (about ·003^{mm} in diameter), prismatic and with abundant protoplasmic contents (fig. 6, c^1). They correspond to the "*geleitzellen*" of Wilhelm, Tschirch* and other authors except that the walls adjoining the sieve tubes, so far as the writer has observed, are not pitted.

At the edges of the phloem, particularly adjoining the xylem, the cambiform cells are larger (often ·01^{mm} in diameter) and are often empty. The differences between these forms are, however, so slight and perplexing that the writer, following the example of De Bary and Strassburger, prefers to group them all under the head of Cambiform cells.

(ϵ) Intercellular spaces, such as occur in the protoxylem of many monocotyledinous plants, are seldom, if ever, seen in coir fibers, but oftentimes, although less commonly than in the hard shell, the phloem and part of the xylem are destroyed during growth, leaving a channel in the bundle.

3. *Endocarp.*

This coat, known commonly as the shell (fig. 8, *end*), is a dense aggregation of stone cells, among which run longitudinally partially destroyed bundles.

(a) *The stone cells* with their thick, deep yellow walls, branching pores, and dark brown contents, present a striking and characteristic appearance. They are either isodiametric or strongly elongated, the latter (often 0·2^{mm} long) being usually spindle or wedge-shaped, although hammer-shaped, hooked and various other curious forms abound.

A study of sections shows that the elongated cells are arranged in groups, commonly with the longer diameters in tangential-transverse directions and are best seen in cross sections of the shell (fig. 8, *qst*), but in some groups, particularly those adjoining the bundles, they pass longitudinally about the shell (fig. 9, *lst*). It is evident from fig. 8 that more than half of all the stone cells are tangentially-transversely elongated. Those which appear isodiametric (*lst*) are partly cells which are isodiametric in three dimensions and partly longitudinally elongated cells in section.

Groups of thinner-walled cells with dark brown contents are occasionally met with.

The brown contents of all the endocarp cells react the same as the brown impregnating material of the mesocarp.

(b) *Vascular bundles* are studied with difficulty in the mature shell. By the rupture of the phloem and part of the

* See Tschirsch, Angewandte Pflanzenanatomie, Wien, 1889, p. 349.

xylem during growth, passages are formed, which, in shells transversely cut or broken, are evident to the naked eye as

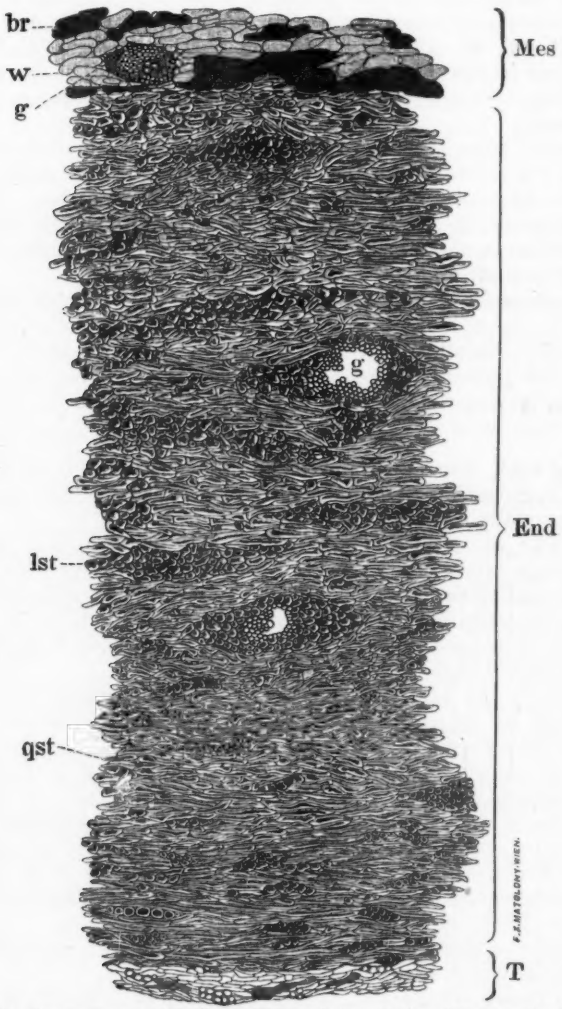


FIG. 8. Transverse section of a cocoanut shell. *End*, endocarp or hard shell; *Mes*, adhering mesocarp; *T*, adhering outer testa; *w*, colorless parenchyma of mesocarp ground tissue; *br*, same as *w* but impregnated with a brown substance; *g*, vascular bundles, in the endocarp with phloem and xylem partially obliterated; *lst*, longitudinally elongated and isodiametric stone cells; *qst*, transversely elongated stone cells. × 60

minute holes. The structure of the bundles is still further obscured by the presence of fungus threads and spores.

In structure the bundles differ from those of the mesocarp fiber, the bast-fibers being replaced by forms intermediate between fibers and tracheids (fig. 9, *f*). The vascular elements are chiefly spiral tracheæ (*sp.*), and pitted tracheæ (*g*), the latter being especially noticeable.

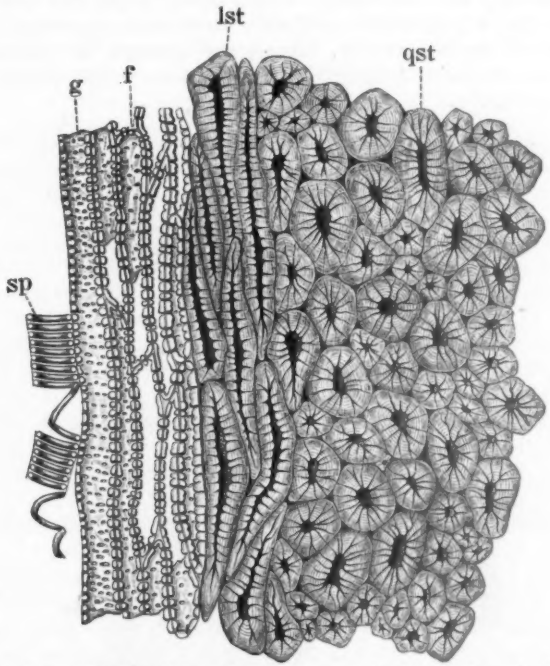


FIG. 9. Longitudinal-radial section of cocoanut endocarp through the stone cells and edge of bundle. *qst*, transversely elongated and isodiametric stone cells; *lst*, longitudinally elongated stone cells; *f*, thick-walled porous cells; *g*, pitted trachea; *sp*, spiral trachea. × 300.

4. *Testa.*

Several microscopists have studied the testa, but, owing doubtless to differences in the material, hardly two of them agree as to the number of coats or the character of the elements. The description which follows is based on the examination of numerous specimens.

(a) *Outer testa.* This coat consists of a ground tissue of large, variously shaped cells, crossing one another in all directions, (fig. 8, *T*, fig. 10), between which ramify the veins.

Most of the ground tissue cells have colorless double walls, from ·004 to ·010^{mm} thick, with conspicuous (sometimes large) pores, but in the inner layers they often have thinner walls without evident pores and except for their shape bear no resemblance to the other cells.

As a rule, the cells are empty, but some here and there contain a brown substance apparently the same as is contained in the mesocarp and endocarp, which often takes the form of spheres (fig. 10, *k*), disks, or films with circular openings (*v*).

Colorless stone cells (fig. 10, *st*) are present in the outer layers and contrast strikingly with the deep yellow stone cells of the endocarp.

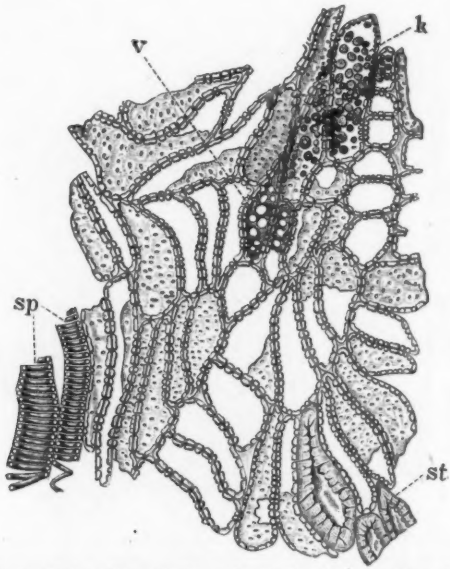


FIG. 10. Tangential section of the outer testa of the cocoanut showing the ground tissue of thick-walled porous cells. Most of these are empty, but a few contain brown contents in the form of globules, (*k*) or films with circular openings (*v*). *st*, colorless stone cell; *sp*, spiral trachea. ×300.

The conspicuous elements of the veins are spiral tracheæ, pitted tracheæ and elongated cells intermediate between pitted tracheæ and the porous cells of the ground tissue, and are not distinguishable from the same elements of the endocarp bundles. (See fig. 9, *sp*, *g* and *f*.)

In breaking away the meat, the separation is through the middle of the veins and the inner layers of the outer testa,

nearly all the ground tissue and about half of the vascular elements remaining on the inner surface of the shell.

(b) *Inner testa.* Firmly attached to the endosperm are from ten to twenty layers of small isodiametric or slightly elongated cells. The double walls are about ·003^{mm} thick and free from pores. These cells contain a material varying in color from light yellow to dark brown, which either fills them completely or occurs in globules, films, etc., as in some of the cells of the outer tests. In the layer adjoining the endosperm the cells are smaller and have darker brown contents than the cells in the other layers.

5. *Endosperm.*

Although the microscopic character of the endosperm has been fully explained by Harz, Hanausek and Moeller, a brief description is here given to accompany the descriptions of the other parts of the fruit.

In the outer layers the prismatic cells are nearly isodiametric (about ·05^{mm} in diameter), but further inward they are radially elongated, often reaching a length of ·3^{mm}. Cell partitions are about ·003^{mm} thick, without pores.

The cells contain bundles of needle-shaped fat crystals and lumps of proteid matter, each lump containing, as a rule, a crystalloid. Ether and alcohol readily dissolve the fat crystals and strong potassium hydrate solution saponifies them. The proteid bodies give the usual color reactions with iodine, Millon's reagent and dyes.

III. The Detection of Powdered Cocoanut Shells in Ground Spices.

The adulteration of ground spices with powdered cocoanut shells was brought to notice in 1885 by W. H. Ellis,* public analyst, Toronto, Canada, and has since been frequently detected by A. McGill † of Ottawa and food analysts in different parts of the United States.

The extent to which this fraud is practiced is indicated by the following summary of results obtained by the writer during the years 1896–7 in the examination of samples collected in the State of Connecticut.

	Black pepper.	Cloves.	Allspice.
Samples examined	147	37	24
Samples adulterated (total)..	47	17	11
Samples adulterated with ground cocoanut shells ...	21	7	6

* Dept. Inland Revenue, Rep. on Adult. of Food for 1885, Ottawa, 1886, pp. 67, 79.

† Laboratory of the Inland Rev. Dept., Bull. No. 20, 1890, pp. 7–11.

It is stated on credible authority that in Philadelphia at the present time about six hundred tons of shells, obtained as a by-product in the preparation of dessicated cocoanut—an article much used in pastries and confectionery—are annually reduced to a powder in mills of peculiar construction and sold to spice grinders. This powder, without further treatment, is mixed with ground allspice, which it closely resembles in appearance. By cautious roasting the color of ground cloves and nutmegs is matched, and by roasting at a higher temperature a charcoal is obtained which, mixed with starchy matter, is a clever imitation of black pepper.

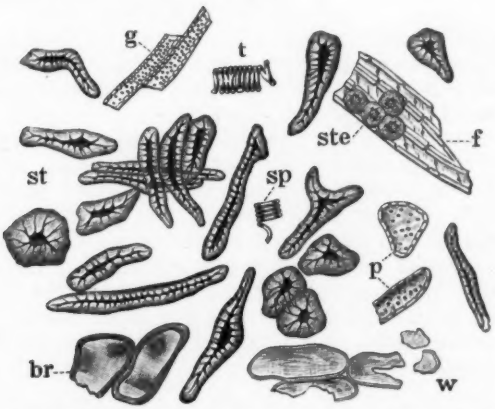


FIG. 11. Cocoanut shell powder. *st*, dark yellow stone cells with brown contents; *t*, reticulated trachea; *sp*, spiral trachea; *g*, pitted trachea; *w*, colorless and *br*, brown parenchyma of mesocarp; *f*, bast-fibers with stegmata (*ste*). ×160.

Powdered cocoanut shells appears to be a distinctively American adulterant. The leading treatises on the microscopy of foods in the German, French and English languages, even those of recent publication, make no mention of it, and a number of prominent European food chemists and microscopists have declared to the writer that they had never heard of its use. On the other hand, cocoanut cake (the residue from the oil presses), which in Europe is commonly employed, both as a cattle food and as an adulterant of human foods, is almost unknown in America.

All the tissue elements of the mesocarp, the endocarp and the outer testa are present in cocoanut shell powder, but the stone cells of the endocarp make up the bulk of the material. (fig. 11, *st*). These cells are characterized by their porous, brown-yellow cell walls, their dark brown contents which

become a reddish brown on treatment with potassium hydrate solution, and the predominance of peculiar elongated forms. They differ in one or more of these characteristics from the stone cells of pepper, allspice, clove stems, walnut shells, almond shells, Brazil-nut shells, hazel-nut shells, peach stones and olive stones.

The outer testa or lining of the shell also forms a considerable part of the powder, the most striking elements being the thick-walled, porous cells (*p*) and the vascular elements.

Colorless cells of the mesocarp ground tissue (*w*) are not distinguishable from the parenchyma of many other plants, but when impregnated with the brown substance which has been described they are striking objects (*br*). Potassium hydrate changes the color of these brown cells to a reddish brown, but ferric chloride does not produce any immediate effect, thus distinguishing them from the brown cells of allspice seed, the color of which potassium hydrate removes and ferric chloride changes at once to a green.

Spiral, reticulated, and pitted tracheæ (*sp*, *t* and *g*), from the mesocarp, endocarp and testa bundles, are also frequently met with in the powder, the pitted trachea being quite unlike any vascular elements of the spices.

The stegmata (*ste*) of the mesocarp fibers with their silicious contents are characteristic, but they are difficult to find owing to the great preponderance of other tissues. Bast-fibers (*f*) are more liable to be encountered than the stegmata, but they furnish less conclusive evidence.

Spices adulterated with charred cocoanut shells show under the microscope black, opaque fragments which are not bleached by aqua regia or nitric acid and potassium chlorate. Except in cases where some of the stone cells or other elements have escaped charring, this material cannot be distinguished from other forms of charcoal.

Chemical analysis is a valuable adjunct to the microscopic examination and often determines approximately the extent of the adulteration, but since other nut shells have a similar composition, the microscope is essential for the identification of the particular adulterant present. As was pointed out by the writer* five years ago, the crude fiber obtained in the process of analysis is particularly suited for the microscopic detection of stone cells and other tissues.

The radical difference in composition between cocoanut shells and the spices to which they are added is shown by the following results by Winton, Ogden and Mitchell.†

* Conn. Agr. Expt. Sta., Rep. 1896, p. 34.
† Ibid., Rep. 1898, pp. 198–211.

	Black pepper. (Av. of 14 analyses.)	Cloves. (Av. of 8 analyses.)	Allspice. (Av. of 3 analyses.)	Nutmeg. (Av. of 3 analyses.)	Cocoanut shells. (1 analysis.)
	%	%	%	%	%
Water	11·96	7·81	9·78	3·63	*7·36*
Total ash	4·76	5·92	4·47	2·28	*0·54*
Ash soluble in water	2·54	3·58	2·47	0·86	*0·50*
Ash insoluble in hydrochloric acid	0·47	0 06	0·03	0·00	*0·00*
Volatile ether-extract	1·14	19·18	4·05	3·02	*0·00*
Non-volatile ether extract	8·42	6·49	5·84	36·70	*0·25*
Alcohol extract	9·62	14·87	11·79	10·77	*1·12*
Reducing matters by direct inversion calc. as starch	38·63	8·99	18·03	25·56	*20·88*
Starch by diastase method	34·15	2·74	3·04	23·72	*0·73*
Crude fiber	13·06	8·10	22·39	2·51	*56·19*
Total nitrogen	2·26	0·99	0·92	1·08	*0·18*
Oxygen absorbed by aqueous extract	....	2·33	1·24	....	*0·23*
Quercitannic acid equivalent to O. absorbed	....	18·19	9·71	....	*1·82*

In conclusion, the author takes this opportunity to thank his highly esteemed instructor, Prof. Dr. Josef Moeller of Graz University, Austria, for kindly assistance in the early part of this investigation. The work was begun in Prof. Moeller's laboratory during the autumn of 1899, but after a year's interruption was finished at this Station.

Acknowledgment is also due Prof. E. Gale of Mangonia, Florida, who generously furnished material for study, and also Herr F. X. Matalony of Vienna, who skillfully reproduced on wood the author's drawings.

ART. XXX.—*Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. WORTMAN. With Plates I–IV.

[Continued from page 206.]

SUBORDER CREODONTA Cope.

IN the first part of this paper, I have given the more important characters by means of which this group of the Carnivora is distinguished from the Carnassidentia. It now seems desirable to enter somewhat more fully into a discussion of these particulars, and I shall therefore consider some of the characters of less importance, from the point of view of classification. The first of these which it is necessary to emphasize as a broadly distinguishing feature is that the Carnassidents have been successful, and have left numerous modified descendants which constitute a large and important part of the living mammalian fauna in almost all regions of the globe; whereas the Creodonts failed, and have completely died out, without possibly the aquatic Pinnipedia represent them in the living Carnivore fauna.

In the organization of the skull, there are a number of characters that are more or less distinctive, among which may be mentioned the large lachrymal spreading out upon the face, as is invariably the case among the carnivorous Marsupials and a number of the Insectivora. This is true of *Mesonyx*, *Dromocyon*, *Harpagolestes*, *Sinopa*, *Proviverra*, *Limnocyon*, *Thereutherium (?)*, and very probably also of *Oxyæna* and *Patriofelis*. In some species, notably the Mesonychidæ, the nasals are broad posteriorly, as in the Marsupials, and almost exclude the frontals from contact with the maxillaries. The posterior border of the palate is terminated by a thickened ridge, recalling to a certain extent the structure of the marsupial palate. In the posterior part of the palate, moreover, there are very generally a large number of foramina of variable size, but usually minute, situated behind the posterior palatine canals, which undoubtedly represent the remains of the vacuities so common to the marsupial skull. In certain forms, especially *Sinopa*, and in some species of *Hyænodon*, as Scott has shown,* there is an additional foramen in the base of the skull, just in advance of the condyloid, which is also a conspicuous feature of the marsupial skull. The zygomatic arch, with its component bones, is heavy, and the malar usually extends well back toward the glenoid cavity. In the superior molars, if either border is elongated it is always the posterior,

* Jour. Acad. Nat. Sci., 1888, p. 178.

and if any of the molars and premolars are especially enlarged, it is never exclusively the fourth premolar above and the first molar below. The scaphoid, lunar, and centrale are very generally free; but according to Cope,* they are united in some French species of *Hyænodon* from the Miocene. In some forms, such as certain of the Arctocyonidæ,† there may also be union of the scaphoid and centrale, as in many carnivorous Marsupials, and the pollex and hallux may be more or less opposable. In some species, the ungual phalanges are relatively broad, flattened, and fissured at their ends, while in others they are laterally compressed, curved, and pointed.

If we now contrast these characters with those of the Carnassidentia, we observe that in them the lachrymal is never spread out on the side of the face, but is confined within the orbit.‡ The nasals are not especially broad posteriorly; the posterior edge of the palate is not thickened; the numerous posterior palatal foramina are absent; there is never a double condyloid foramen, and it is always the anterior border of the superior molars that is elongate, if either.§ If there is enlargement and specialization of any of the teeth it is always the fourth superior premolar above and the first true molar below. From the Upper Eocene stage onward, the scaphoid, lunar, and centrale are always united, and there is never union of scaphoid and centrale alone. The bony claws are always curved, compressed, and pointed.

Present evidence points to the fact that the two groups probably arose side by side from the Mesozoic Marsupials,‖ although we do not know any true Carnassidents earlier than the Torrejon, while certain of the Creodonts come from the Puerco.

Quite recently, Matthew¶ has classified the Creodonta as follows:

* Tertiary Vertebrata, p, 256.

† See Matthew, Bull. Amer. Mus., Nat. Hist., Jan., 1901, p. 14.

‡ The only exception to this statement with which I am acquainted is found in the viverrine *Eupleres gondati*, from Madagascar, which otherwise resembles the Insectivores.

§ An apparent exception to this is found in *Palæonictis*, in which the posterior border of the first molar is slightly longer than the anterior.

‖ I here use the term Marsupials in its larger sense, or as equivalent to the Metatheria of Huxley. It would appear to be more or less doubtful whether the existing Marsupials furnish a stage of embryonic development immediately antecedent to that of the appearance of a distinct allantoic placenta. Just how far they may have departed from their Mesozoic ancestors in this respect we shall never, perhaps, be able to ascertain, but there cannot be the slightest doubt of the fact that a preplacental stage existed, from which the placental had its origin. While it may not have been exactly like that seen in the living Marsupials, it must have, according to the very nature of the case, resembled it in a great many important particulars.

¶ Loc. cit., p. 7.

"I. CREODONTA PRIMITIVA. No specialized carnassial; tritubercular upper and lower molars; shear rudimentary or absent. Claws unknown.

Oxyclænidæ. Includes some genera with Lemuroid affinities in the dentition.

II. CREODONTA ADAPTIVA. Carnassial, when present, on $p.^4$ and $m._1$. Claws, where known, of modern type and carried probably more or less free of the ground. Scapholunar-centrale early uniting (podials tending towards true Carnivore type).

1. Post-carnassial teeth disappearing ..... *Paleonictidæ.*
2. Post-carnassial teeth becoming tubercular ..... *Viverravidæ.*
3. No carnassials; molars becoming flat-crowned; premolars disappearing ..... *Arctocyonidæ.*

III. CREODONTA INADAPTIVA. Carnassial, when present, not on $p.^4$ and $m._1$. Claws, where known, blunt, hoof-like, resting on the ground. No tendency of union of the carpals (podials tending toward Ungulate type).

1. Carnassials $m.\frac{1}{1}$ shearing teeth ..... *Oxyænidæ.*
2. Carnassials $m.\frac{2}{3}$ shearing teeth ..... *Hyænodontidæ.*
3. No carnassials; teeth with high, round, blunted cusps; upper molars tritubercular; lower molars premolariform ..... *Mesonychidæ.*"

This classification is of course based upon the older conceptions of the limitations of the group, and differs materially from that herein proposed. For example, the Palæonictidæ and Viverravidæ have been removed to the Carnassidentia, the reasons for which have been fully set forth on a preceding page. This leaves only the single family Arctocyonidæ in Matthew's group "Creodonta Adaptiva." This family, as has already been suggested, stands much nearer to the carnivorous Marsupials in the organization of the feet than to any Carnassident. The union of the scaphoid and centrale, the marked tendency to opposability of both pollex and hallux, the character of the fibulo-astragalar articulation, as well as the compressed, curved, and pointed claws, are almost exactly paralleled in the case of the living Dasyures. Moreover, it is highly probable that this family will be found to be further characterized by the extra-orbital extension of the lachrymal and the double condylar foramen. In the light of these facts neither the genus nor the family can be regarded as having any very close affinities with the Carnassidentia.

In this connection, it is important to state that Cope, in his description* of the fragmentary skeletal material of *Clænodon ferox* at his disposal, compared it carefully with the carnivorous Marsupials *Didelphys*, *Sarcophilus*, and *Thylacynus;* he pointed out a number of similarities of structure to these forms

* Tertiary Vertebrata, 1884, p. 330.

and concluded that "its nearest living ally is the *Thylacynus cynocephalus* of Tasmania." In opposition to this view, Matthew observes*—"Clænodon has, however, no marsupial characters except such as may be considered an inheritance from a common stock, which gave rise to both Marsupials and Placentals. Its progressive characters are placental carnivore." Just how this latter author explains the remarkable resemblances of foot structure in the two groups, including the marked tendency towards opposability of pollex and hallux, or what constitutes the so-called progressive characters of which he speaks, other than these same marsupial characters, I am at a loss to imagine. In my judgment Cope's position rests upon very sound anatomical reasoning, the force of which is rendered all the more patent by these later discoveries.

As regards the third group, I am compelled to add that I find myself unable to accept the definition as accurate, or the grouping as natural. If by the term carnassial is meant the *most specialized* cutting teeth of the series, then the definition is fairly satisfactory, but the character would have been much better and more clearly expressed, had it been stated what teeth are sectorial. The character of the ungual phalanges, and their supposed manner of articulation, I do not regard as of any very great value in the classification of the major divisions of this group, for the reason that within the limits of one of the families, at least, their structure ranges from the compressed, curved, and sharp-pointed variety, to the flattened, depressed, and fissured type.

The statement that the podials are tending toward an "Ungulate type" is such an extraordinary one, and is so at variance with the facts, especially as regards the Oxyænidæ and Hyænodontidæ, that I can hardly believe that the author intended it to apply to these families. It is true that the feet of the Mesonychidæ, in the later members, assumed a more or less "Ungulate type," because of a highly developed running habit, just as, among the living Carnassidents, the limbs of the modern Canidæ have taken on a similar structure from a like cause. But to suppose that there is even the faintest suggestion of anything "Ungulate" in the foot structure of such forms as *Sinopa*, *Limnocyon*, *Oxyæna*, *Patriofelis*, or *Hyænodon*, other than the fissured claws in the last three genera, is certainly quite beyond the facts.

The association, moreover, of the Mesonychidæ with the Oxyænidæ and Hyænodontidæ is not very apt, since in point of structure it is widely separated from these two families, and constitutes one of the most distinct and separate groups of

* Bull. Amer. Mus. Nat. Hist., 1901, p. 12.

the suborder thus far known. I define the five families as follows:

Oxyclænidæ. No specialized carnassials; tritubercular upper and lower molars; shear rudimentary or absent (Matthew).

Genera: *Oxyclænus, Chriacus, Protochriacus, Deltatherium,* and *Tricentes.* All from Lower and Middle Eocene.

Arctocyonidæ. No carnassials; molars flat-crowned; premolars becoming progressively reduced in size; scaphoid and centrale early united; hallux and pollex more or less opposable; claws compressed, curved, and pointed.

Genera: *Arctocyon, Clænodon,* and *Anacodon.* From Lower and Middle Eocene.

Mesonychidæ. No carnassials; molars with characteristic, high, bluntly conical cusps, superior tritubercular, inferior becoming premolariform; claws depressed, little curved, and fissured; limbs in later forms becoming much modified in accordance with running habit.

Genera: *Triisodon, Goniacodon, Sarcothraustes, Dissacus, Pachyæna, Mesonyx, Dromocyon,* and *Harpagolestes.* From Lower, Middle, and Upper Eocene.

Oxyænidæ. Pm.^{4} and M.$\frac{1}{1,2}$ carnassial, of which M.$\frac{1}{2}$ are largest and most specialized; claws, as far as known, depressed, little curved, and fissured.

Genera: *Oxyæna, Patriofelis, Limnocyon, Oxyænodon,* and *Thereutherium.* From Middle and Upper Eocene.

Hyænodontidæ. Pm.^{4} and M.$\frac{1,2}{1,2,3}$ carnassial, of which M.$\frac{2}{3}$ are the most specialized, especially in the later types; claws depressed, little curved, and fissured; or compressed, curved, and pointed; in early types a double condyloid foramen as in Marsupials.

Genera: *Sinopa, Proviverra, Hyænodon, Pterodon, Quercytherium, Cynohyænodon, Palæosinopa,* and *Didelphodus.* From Middle and Upper Eocene and Oligocene.

Family Mesonychidæ Cope.

This family is represented at the very beginning of the Tertiary by the genus *Triisodon,* with three well-marked species from the Puerco of New Mexico. In the succeeding Torrejon beds of the same region, three generic modifications make their appearance; namely, *Sarcothraustes, Goniacodon,* and *Dissacus.* The first of these has been properly regarded as the direct descendant of *Triisodon,* while the last represents the beginning of the *Mesonyx* line of succession. The first three of these genera—*Triisodon, Sarcothraustes,* and *Goniacodon*—have been considered by Cope and Scott to represent a distinct family, Triisodontidæ, but I have shown* that their classification is probably best accomplished by placing

* Bull. Amer. Mus. Nat. Hist, June, 1899, p. 146.

them as a subfamily of the Mesonychidæ. The differences which distinguish them from the Mesonychinæ are not great, and consist in the deep, heavy lower jaws, with powerful symphysis, together with the much wider, more typically tuberculär upper molars, as well as the more subequal size and normal arrangement of the cusps of the trigon of the lower molars.

While the Triisodont division became extinct at the close of the Torrejon, in *Dissacus* we have the beginning of the *Mesonyx* line, which continued through the whole of the Eocene, being represented in the several stages by a number of species and genera, and towards the close of its career, as we shall presently see, developed a limb structure almost equaling, if not actually surpassing, that of the modern dogs in point of specialization for a running habit. The connections between these two extremes are close, the interval being completely bridged by the Wasatch *Pachyæna*. In *Dissacus*, the feet are relatively short and stout; they are pentadactyle and the toes were spreading, a condition which was gradually modified into the four-toed, compressed, elongated feet of the cursorial *Mesonyx*. I define the known genera of the Mesonychinæ as follows:

I. Digits, 5–5; humerus with an entepicondylar foramen.
   a. Internal cusps of inferior molars distinct; posterior external cusps of superior molars smaller than anterior; M.$\frac{3}{3}$, Pm.$\frac{4}{4}$ ... *Dissacus.*
   b. Internal cusps of inferior molars vestigial; external cusps of superior molars equal; M.$\frac{3}{3}$, Pm.$\frac{4}{4}$ ... *Pachyæna.*
   c. Internal cusps of inferior molars vestigial; external cusps of superior molars equal; M.$\frac{2}{3}$, Pm.$\frac{3}{4(?)}$ ... *Harpagolestes.*

II. Digits 4–4; humerus without entepicondylar foramen.
   a. M.$\frac{3}{3}$ ... *Dromocyon.*
   b. M.$\frac{2}{3}$ ... *Mesonyx.*

Subfamily Mesonichinæ.

Harpagolestes macrocephalus gen. et sp. nov.

The remains upon which this genus and species are founded consist of the greater portion of a skull, together with a complete humerus of the right side, a distal end of a femur, and a centrum of an axis, all belonging to one individual. With the exception of considerable vertical crushing, the anterior portion of the skull is well preserved, including most of the teeth. The posterior part of both mandibular rami are present, with

most of the teeth *in situ*. These remains indicate an animal somewhat larger than *Mesonyx uintensis* of the Uppermost Eocene-stage, which has hitherto been considered the largest Carnivore of the Eocene. The skull exceeds that of a full-grown Grizzly Bear, but the body was not as large in proportion.

The principal generic characters have already been stated in the foregoing analytical table. Those which distinguish it most sharply from the contemporary *Dromocyon* and *Mesonyx* are seen in the reduced number of superior premolars and the presence of an entepicondylar foramen in the humerus. Additional characters of importance are: The absence of a supertrochlear foramen of the humerus, the lack of complete molariform structure of the fourth superior premolar, together with the absence of the third superior molar. I have provisionally placed this form in the section having five toes on each foot, largely on account of the unspecialized condition of the humerus, which resembles that of *Pachyæna* more closely than *Mesonyx* or *Dromocyon*. The foot structure is unknown, but we can readily believe that the toes were not so much reduced as in the more specialized genera.

The Skull. (Plate I.)—The muzzle appears to be proportionally longer and wider than that of either *Dromocyon* or *Mesonyx*. The nasals spread out posteriorly, as in these genera, leaving only a narrow contact between frontal and maxillary. This condition is associated with the large extra-orbital extent of the lachrymal, which is spread out upon the side of the face, as in all the Mesonychids. The orbit is relatively more posterior than in *Dromocyon* or *Mesonyx*, and the lachrymal canal is single, rather small, and placed within the rim of the orbit. The premaxillæ are of moderate size, articulating freely with the nasals above, but not extending backward to join the frontals; they terminate posteriorly just above the infraorbital foramen, which is relatively large and issues above the middle of the third premolar. The brain-case and posterior frontal region are not well preserved, but there is evidence of a distinct postorbital process and a high sagittal crest. The palate is long and rather narrow; the opening for the posterior nares is placed well behind the posterior termination of the tooth line, at the thickened terminal border of the hard palate. Behind this the narial groove is narrow and not very deep, the opposite pterygoid plates approaching each other below in such a manner as to leave a rather narrow opening. This is similar to the arrangement seen in the skull of many species of *Hyænodon* and is particularly noticeable in *Mesonyx uintensis*, as figured by Osborn.* The incisive foramina, or anterior

* Bull. Amer. Mus. Nat. Hist., 1894, p. 80.

palatine fossa, is relatively small and situated somewhat in advance of the canine; posteriorly, opposite the interval between the fourth premolar and first molar, are seen the palatal openings of the rather large posterior palatine canals, and behind these occur numerous smaller openings of variable size, which, as in so many other cases among the Creodonts, undoubtedly represent the vacuities of the marsupial palate.

The zygomata are strong and massive, with considerable outward arching. The malar extends well forward upon the face, furnishing the entire inferior boundary of the orbit, and upon the under side of the arch, at the point of junction with the maxillary, develops a prominent process which doubtless served for the attachment of one of the principal tendinous origins of the masseter muscle. It passes backward in the usual way into the zygomatic process of the squamosal, terminating at a considerable distance in advance of the glenoid cavity. This cavity is large and roomy, and is terminated in front and behind by strong anterior and posterior glenoid processes. There is a small, rugged, slightly inflated, otic bulla, developed apparently from the tympanic, as in *Dromocyon vorax*. The foramen ovale is situated much as in this species, and there is satisfactory evidence of the existence of both an alisphenoid canal and a large postparietal foramen. The posterior region of the skull is otherwise too much broken to admit of a more extended description, further than to add that the occiput was apparently of the same narrow, elevated, overhanging type as that of *Dromocyon vorax*.

The lower jaw is deep posteriorly, the coronoid is comparatively little elevated, and exhibits that characteristic backward shape common to all the members of the family. The masseteric fossa is broad and shallow and the angle is strongly inflected as in the Marsupials. The condyle is broad and heavy, and of a half-cylindrical pattern. The symphyseal region is not preserved.

Dentition.—The dental formula, as far as at present known, is as follows: I.$\frac{3}{1}$, C.$\frac{1}{1}$, Pm.$\frac{3}{4(?)}$, M.$\frac{2}{3}$. Of the superior series, the crowns of the incisors are not preserved, but judging from their alveoli, they were of the pattern and relations common to a large number of the Creodonts. They were arranged in a semicircle in the premaxillæ, the outer pair being considerably larger than the other two, and separated from the canine by a short diastema. The canine is large and powerful; it is subround on cross-section at the base of the crown, and is deeply implanted in the maxillæ; there were apparently no anterior or posterior cutting ridges developed. The first premolar is small, with a slightly hook-shaped crown, and is implanted by a single root close to the base of the canine, like the corre-

sponding tooth in the skull of certain species of *Ursus*. The second premolar has completely disappeared, a long diastema intervening between the first and third. The third premolar is implanted by two powerful roots; its crown is composed of a single, large, antero-median conical cusp, with a marked posterior swelling, which in the unworn condition may have borne a more or less distinct basal talon, or heel. The crown of the fourth premolar, like those of the succeeding molars, is much worn and does not display very clearly the arrangement of the cusps; it is supported by three roots, and, in the unworn condition, there were apparently two external and one internal cusps. Of the two external the anterior was evidently much the larger, so that the crown cannot be said to have been fully molariform. The cusps of the molars cannot be determined satisfactorily, but it may be assumed that the first molar had the typical three subequal cusps, and that the crown of the second was more or less degenerate. The crowns of the lower molars are also in a much worn condition; the third is, however, sufficiently unworn to show the simple premolariform arrangement of the cusps, a condition which without much doubt obtained in the teeth in advance. The incisors and anterior premolars of this series are wanting in the specimen.

44

FIGURE 44.—Right humerus of *Harpagolestes macrocephalus* Wortman; front view; one-fourth natural size. (Type.)

The humerus, figure 44, is small in comparison with the size of the skull. This proportional disparity between the size of the head and body is true of quite a number of the Creodonts, but not of all of them, as will be shown later. The *caput* has a pyriform outline, well rounded in both directions, and overhangs the shaft posteriorly. The greater tuberosity is large and rises considerably above the level of the head. The tendinal impressions for the attachment of the *spinati* and *teres minor* are large, roughened, and very distinct, indicating unusual strength for these muscles. The bicipital groove is wide and is placed well upon the inner side of the bone. The lesser tuberosity is prominent, and there is a large rugose area for the insertion of the subscapular tendon. There is a power-

ful deltoid crest, which extends well down the shaft. As in all the later Mesonychids, the distal extremity has the appearance of being compressed from side to side, resulting from the decrease in size of the supinator ridge and internal condyle, in marked contrast with the broad extremity of this bone in the earlier forms. The internal condyle, while reduced, exhibits an entepicondylar foramen for the passage of the principal vessels and nerves to the forearm, although the bony bridge covering it is small. The condyle is considerably enlarged posteriorly and is separated from the inner edge of the trochlea below, by a deep notch. The anconeal and anticubital fossæ are deep, but there is no supertrochlear foramen. Of the articular surface the *capitellum* is distinct, wedge-shaped, and separated from the trochlear groove by a tolerably distinct ridge. The trochlear groove is wide and moderately deep; the inner edge is unusually prominent and extends considerably below the general level of the articulation.

With the exception of a distal end of a femur, which does not offer any characters of especial interest, no other limb bones are certainly known.

The principal measurements are as follows:

	mm.
Length of superior dental series from incisive border	197·5
Width between outer border of incisors	54·
Antero-posterior diameter of canine at base of crown	31·
Transverse diameter of canine at base of crown	23·
Length of canine including root	135·5
Length of molar and premolar series from posterior border of canine	138·5
Length of diastema between first and third premolars	29·
Length of true molars (antero-posterior)	44·5
Transverse diameter of first molar (posterior border)	26·
Transverse diameter of second molar	21·5
Length of palate from incisive border to posterior narial opening	222·5
Width of palate between the canines	39·5
Width of palate between last molars	65·
Length of humerus	275·
Transverse diameter of head	54·
Width (transverse) of distal end	67·5
Length of lower molar series	83·
Depth of lower jaw at last molar	85·5

The specimen is from the lower part of the Bridger Beds, near the mouth of Smith's Fork, and was found by R. E. Son.

Dromocyon vorax Marsh.

Dromocyon vorax Marsh. This Journal, vol. xii, July, 1876, p. 403.

The second genus of this subfamily to be considered is *Dromocyon*, and fortunately the remains upon which it was founded consist of a nearly complete skeleton of a single individual, in magnificent preservation. In his original description of this genus and species, Professor Marsh states: "A new and remarkable carnivorous mammal about the size of a large wolf is represented in the Yale Museum by a nearly complete skeleton. In the form of the skull, and general character of the jaws and teeth, the genus resembles *Hyænodon*. In the present specimen there were apparently but two lower incisors in each ramus. There are seven lower molar teeth, and the last lower molar is small. The top of the skull supported an enormous sagittal crest. The brain was small and convoluted. The lower jaws are long and slender, and the condyles low. The femur has a small third trochanter, and the astralagus a facet for the cuboid. There were four toes in front, and four behind."

This description, as will be seen from the analytical table given above, does not distinguish the genus sufficiently from *Mesonyx* or other members of the subfamily. Cope recognized two species of *Mesonyx* from the Bridger horizon, *M. obtusidens* and *M. lanius*.* The latter of these was originally described as a separate and distinct genus, *Synoplotherium*, which, however, was afterward abandoned as indistinguishable from *Mesonyx*. The type specimen of *M. lanius* consists of a portion of the skull, together with one fore foot more or less complete, and numerous fragmentary parts of the skeleton of a single individual, from the lower levels of the Washakie Basin.

Of this specimen, which is the only one thus far known, Cope,† in speaking of the incisor region of the lower jaw, says: "The most remarkable feature of the genus is seen in the inferior canines. These are very large teeth, and are directed immediately forwards, as in the cutting teeth of rodents. They work with their extremities against the retrorse crowns of the two external incisors above, and laterally against the superior canine. They are separated by a space about equal to the diameter of one of them. In this space I find no alveoli nor roots of teeth; the outer alveolar wall extends far beyond the inner. The latter terminates opposite the middle of the superior canine. It may be that there are no inferior incisors."

While the structure of the fore foot as well as other comparable parts of the skeleton of *Dromocyon vorax* agree very closely in size and other respects with the description and

* Tertiary Vertebrata, 1884, pp. 348, 362. † Loc. cit., p. 359

figures of *M. lanius*, as given by Cope, there is no such arrangement of inferior canine and incisors as above described. It may possibly be that the condition of Cope's type of *M. lanius* is abnormal in this respect, and that *Dromocyon vorax* is the same as *M. lanius;* but until this is confirmed or disproved by additional specimens, I feel bound to regard the two forms as distinct. A further reason for such a course lies in the fact that the two specimens are from widely separated localities in different basins, *M. lanius* coming from the Washakie, and *Dromocyon* from the Bridger.

The Skull. (Plates II–IV.)—Like all members of the Mesonychidæ thus far known, the skull is large in proportion to the size of the body; its length is equivalent to that of $15\frac{1}{2}$ vertebræ counting from the first dorsal backward, or it is about one and one-half times the length of the femur. When compared with a large specimen of *Canis familiaris* (Bloodhound), the size of the two skeletons being about equal, the length of the skull is seen to be quite one-half greater. In this specimen of the dog, the length of the skull is equal to that of only 10 vertebræ counting from the first dorsal backward, or is just about equal to that of the femur.

The muzzle is of moderate length and height, slightly constricted behind the canines, and obliquely truncated in front. The anterior narial opening looks forward and a little upward. The premaxillæ exhibit the form and relations usual among the Carnivora; they articulate freely with the nasals above, but do not send up a process to join the frontals behind, as in many Carnivores. The nasals are broad posteriorly, and in connection with the lachrymals almost exclude contact between frontals and maxillæ, as in certain carnivorous Marsupials, notably *Sarcophilus* and *Didelphys*. As in these latter forms, owing to the large size of the lachrymals, the maxillæ are excluded from any share in the boundary of the orbit, whereas in all the Carnassidents, with the exception of *Eupleres*, the posterior edge of the maxillary reaches the anterior rim of the orbit. The infraorbital foramen is large, and has its usual position above the posterior border of the third premolar. The orbit is relatively small, as in *Sarcophilus* and the opossum, in marked contrast with its large size in the great majority of the Carnassidents: its anterior border lies above, and coincides with, the anterior edge of the second molar. As already mentioned, the lachrymal is large and spreads out upon the face to a considerable extent; it carries a very prominent lachrymal tubercle, as in many of the Marsupials, but the lachrymal canal is simple and opens within the rim of the orbit, as in the Carnassidents. There are well-developed postorbital processes of the frontals, and corresponding though less distinct processes

on the malars, marking the posterior boundaries of the orbital cavities below. The zygomatic arches are rather broad and heavy; they are widest a short distance in advance of the glenoid cavity and apparently lack the graceful outward curving so common to the carnassident skull, although it is difficult to say just how much of this appearance is due to post-mortem pressure. In their present form they resemble those of the opossum. The malar has a considerable extension upon the side of the face, and displays a prominent median ridge, which is continued forward to the infraorbital foramen. On the under surface of the arch, at the point of junction of the malar with the maxillary, there is a prominent process for the tendinous origin of the most anterior fibers of the masseter. This process is apparently wanting in the carnassident skull, but is large and prominent in that of the Opossum, Dasyure, and to a less extent in *Sarcophilus*.

The postorbital constriction is marked, and as in the Marsupials, the brain cavity is relatively very small. Just posterior to this constriction the diverging branches of the postorbitals unite to form an enormous sagittal crest, which passes back to the high, narrow, overhanging occiput. At the base of the crest, opposite the external auditory meatus, is seen the superficial opening of the unusually large postparietal canal,—a venous foramen which served as a conduit for the venous blood passing to the lateral sinus.

The posterior view of the cranium, Plate III, shows the occiput to be very high and narrow, and at the same time, extending considerably beyond and overhanging the condyles; it exhibits a very rugose surface for the attachment of the nuchal muscles, and near the middle portion there is a localized roughened area for the origin of the nuchal ligament. The lambdoidal crest is broad and laminate above, less distinct and more spreading below, and passes around upon the squamosal in the usual manner, to become continuous with the posterior root of the zygoma. The condyles are large, protuberant, and divergent, and the foramen magnum looks backward and downward. The mastoid has quite an extensive exposure upon the postero-lateral part of the occipital surface, but no greater than that of the opossum or dog; it becomes prominent laterally and forms a moderately large mastoid protuberance, similar to that of the bears and the arctoid Carnassidents in general. Upon the posterior surface of this process is seen the external opening of the large stylomastoid foramen, and in front of and a little below this is a rather deep recess, which probably marks the point of attachment of the hyoid arch, although there is no plug-like tympanohyal present. This posterior position of the stylomastoid foramen appears to be peculiar to certain of the

Creodonts; it has a similar position in *Oxyæna* and *Patriofelis*, and probably also in *Hyænodon*, but of this latter genus I cannot speak with certainty. In the marsupial skull its opening is upon the under and more or less anterior surface of the bone, as it is in Carnassidents. The paroccipital process is rather small and has more of a backward and outward than downward direction. Between the mastoid and exoccipital there is a deep fissure, which at its upper extremity is pierced by a foramen, as in the dog.

Upon the under surface of the skull, Plate IV, the basioccipital is rather narrow and the point at which it articulates with the basisphenoid is much roughened for the attachment of the *recti capiti* muscles. Immediately in advance of the condyles is seen the single pair of large condyloid foramina. The tympanic bullæ are of moderate size, rugose, and apparently developed exclusively from the tympanic, without inflation of any part of the alisphenoid, as in the Marsupials. The external auditory meatus is rather long and tubular and opens between the mastoid and postglenoid. At the postero-internal angle of the bulla is placed the irregular opening of the foramen lacerum posterius, which is probably also the point of entrance of the internal carotid artery, although I am unable to discover any very distinct canal which answers to this foramen in the carnassident skull. At the anterior extremity of the bulla are the openings of the foramen lacerum medius and the eustachian tube, and immediately in advance of these, on the prominent ridge leading forward from the internal edge of the glenoid cavity, are situated the foramen ovale and the posterior opening of the alisphenoid canal.

One of the most conspicuous features of the base of the skull is the very large size and low position of the glenoid fossæ; they are supported upon unusually thick, heavy processes of the squamosals, which project much below the level of the base of the skull. The cavity is relatively deep, and is spout-like and transverse, the depth being considerably augmented by the unusually prominent anterior and posterior glenoid processes. The pterygoids are broad, thin, wing-like, and project considerably below the base of the skull and the level of the palate. The postnarial groove is continued well forward; it is deep, rather narrow, but there is apparently no tendency for its palatine boundaries to arch it over below, as in *Hyænodon*. The optic foramina are distinct from each other and occupy their usual position in the carnivorous skull, just in advance of the sphenoidal fissure. In front of and a little above the optic, near the junction of the frontal with the orbitosphenoid, is a small but distinct opening which corresponds to the anterior ethmoidal foramen of human anatomy, for the passage of the

nasal nerve. The anterior sphenoidal fissure and foramen rotundum are apparently distinct, although a slight crushing of this region of the skull renders this somewhat uncertain; they seem to open externally in a circular depression common to these two and the anterior opening of the alisphenoid canal.

The palate is rather long and narrow. The anterior palatine fossæ have a position well forward and are more or less slit-like. The posterior palatine canals are of moderate size and are placed opposite the fourth premolar, which nearly coincides with the anterior limit of the palatine bones. Posterior to these are some eight or ten minute openings which in all probability are vestiges of the vacuities of the marsupial palate. The posterior edge of the palate is considerably thickened, and between the posterior extremity of the maxillary and the palatine is a deep grove, the function of which is not very clear.

The lower jaw of the individual under consideration is of unusual pathological interest, as showing, among these ancient animals, the result of healing of a fracture. During life the horizontal ramus of the left side had been broken near the middle portion, opposite the second molar, and had completely healed without any apparent shortening. The posterior portion had, nevertheless, been displaced upward, and a large exostosis formed upon the outside, involving at the same time the inferior border of the horizontal ramus.

The right ramus is, however, normal and may be described as long and moderately slender. The symphysis is strong and extends to beneath the anterior border of the third premolar. Anteriorly, upon the side of the horizontal portion, are two mental foramina, the larger of which is situated beneath the first premolar and the smaller beneath the anterior portion of the third premolar. The coronoid is of moderate height and displays the characteristic backward slope, peculiar, as far as I am aware, to all members of the subfamily; it lacks the usual high falcate pattern so common to the Carnivora. The masseteric fossa is broad and shallow and does not exhibit the strong ridges for muscular attachment of the more typical biters. The condyles are heavy, of half-cylindrical pattern, and supported upon rather long, stout necks. The angle is prominent and considerably inflected, as in the Marsupials. Indeed, the posterior region of the mandible exhibits so many striking peculiarities that, in the absence of other parts of the skeleton, it would be quite sufficient to distinguish the subfamily without difficulty.

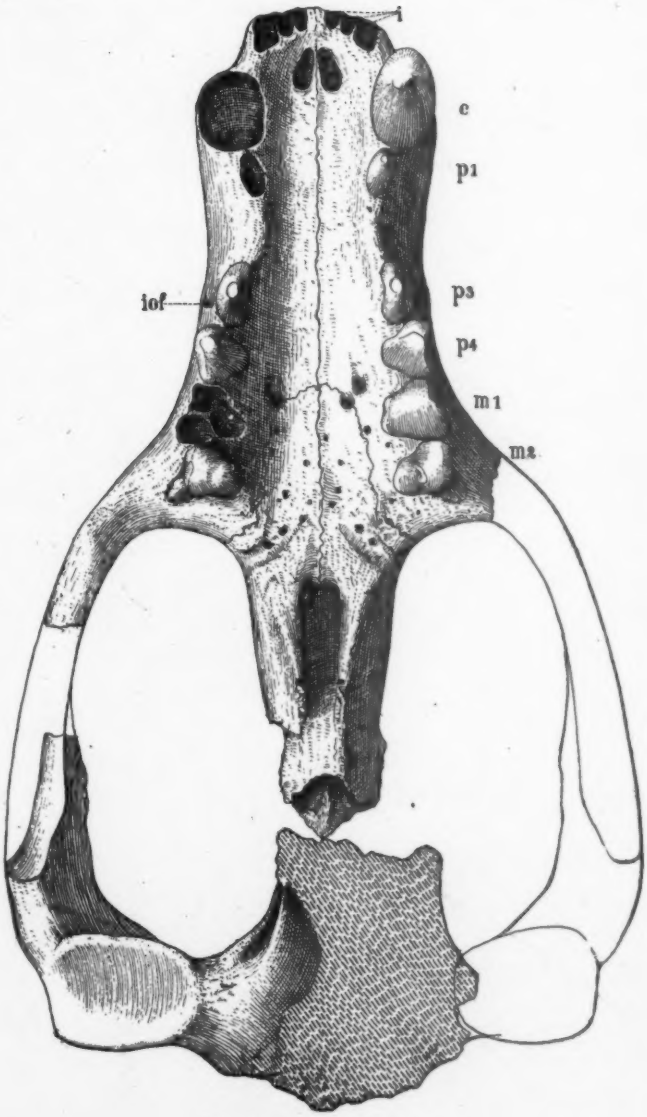
Dentition.—The teeth are in such a worn condition that they furnish very unsatisfactory information of their structure. They were, however, so nearly like those of *Mesonyx obtusidens*,

fully described by Scott,* that if one can judge from appearances, there will be little difficulty in supplying the deficiencies. The formula of the specimen is I.$\frac{3}{?}$, C.$\frac{1}{1}$, Pm.$\frac{4}{4}$, M.$\frac{3}{3}$, but there is reason to suspect that the senile condition of the individual may be responsible for the presence of so few incisors in the lower jaw. In the superior series there are three incisors indicated upon each side, of which but a single one remains in place in the jaw. The alveoli for the others are shallow and apparently partially closed up, which would indicate that they were to a certain degree caducous. They were, however, implanted in the jaw in the ordinary way, and were very little, if at all, procumbent. The canines are indicated by their large elliptical alveoli, which penetrate deeply into the maxillæ. The first premolar is single rooted and follows immediately behind the canine without diastema. The second is two-rooted and had a crown in the unworn condition, composed evidently of an anterior conical and a posterior basal cusp. The third is likewise two-rooted, with a similarly constituted crown. The fourth is three-rooted, and was therefore, a three-cusped tooth of which there were apparently two subequal external and one internal, being thus fully molariform. The two succeeding molars are of the same size, and, as nearly as can be determined, their crowns have the same composition. The last molar was considerably reduced, but the structure of its crown cannot be made out.

In the inferior series there is but a single pair of incisors, but, as already remarked, the advanced age of the individual at the time of its death may have had something to do with this condition. Such a view is rendered all the more probable by the fact that the tooth pertaining to the right side, which still remains in place, lies close to the canine, while its fellow of the opposite side, or at least what appears to be such, is implanted almost directly in the middle of the alveolar border. The canines, of which the right remains *in situ*, are of large size and upright position. The crown of the one preserved is badly worn, and, in consequence, is very blunt and rounded. The wear resulting from contact with the corresponding tooth in the upper jaw is postero-lateral, and hence normal, so that it can be definitely stated that they had no such position as Cope has described in *Mesonyx lanius*. With the exception of the single-rooted, simple-cusped first premolar, all the succeeding teeth have the bicuspidate premolariform structure of *Mesonyx*. The last molar is notably smaller than the rest and is implanted well up on the sloping border of the coronoid. This gives a peculiar and characteristic curved line of implantation.

* Jour. Acad. Nat. Sci., Phila.

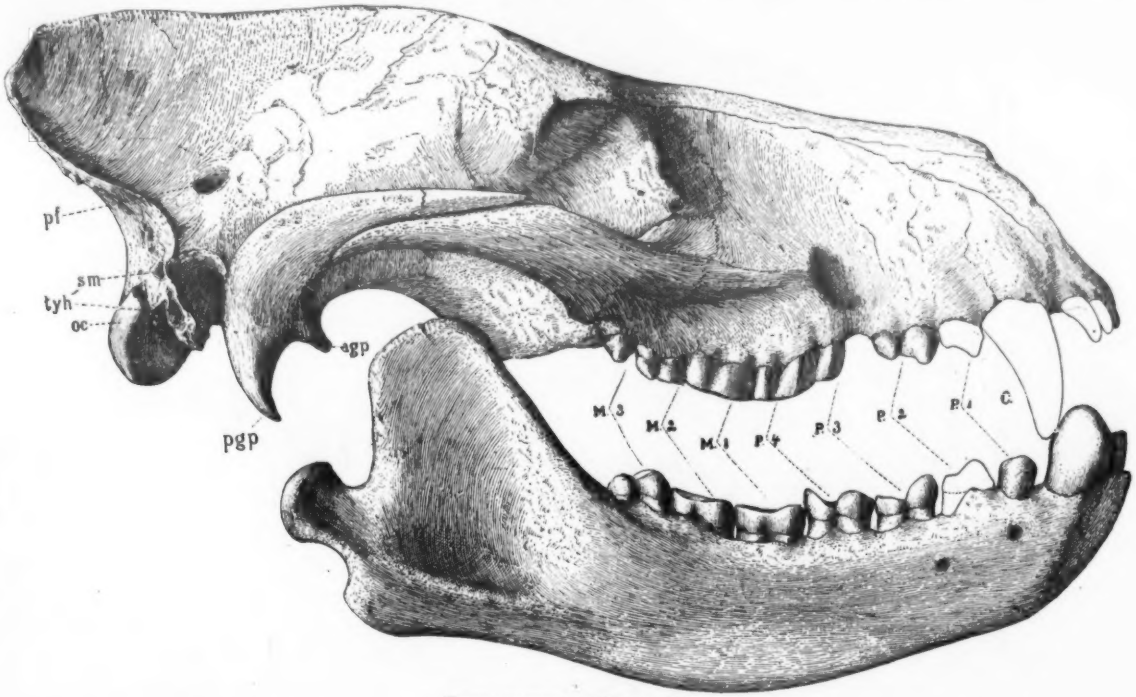
[To be continued.]



EXPLANATION OF PLATE I.

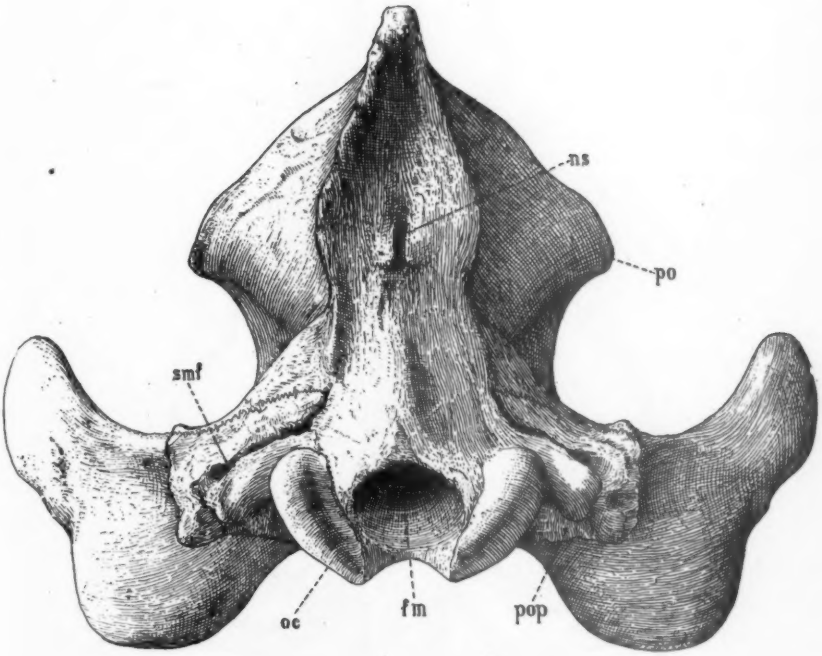
Skull of *Harpagolestes macrocephalus* Wortman; under view; three-eighths natural size. (Type.)

iof, infraorbital foramen.



EXPLANATION OF PLATE II.

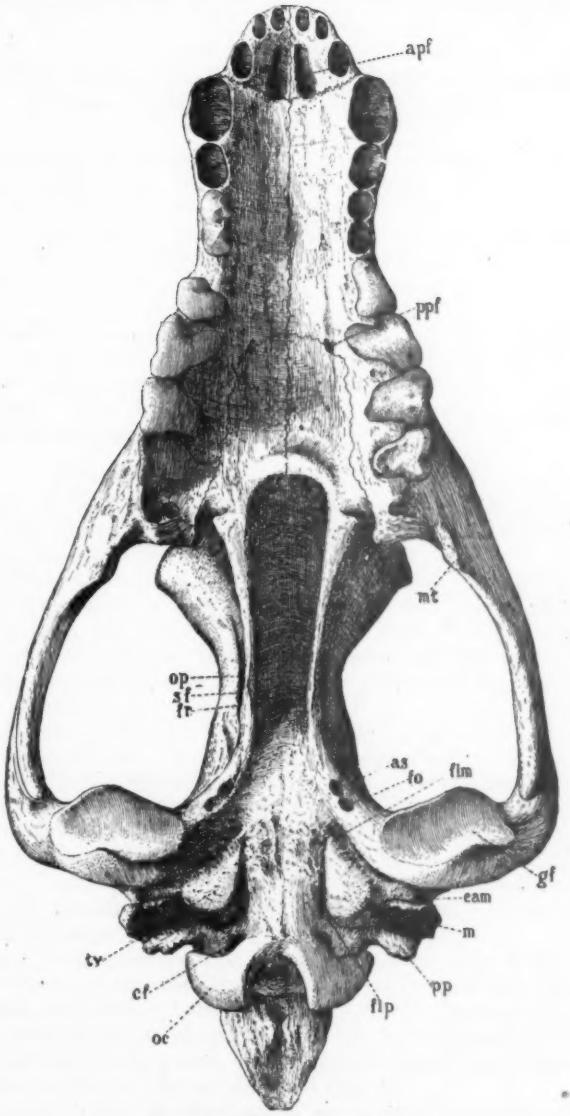
Side view of the skull of *Dromocyon vorax* Marsh; one-half natural size. (Type.)
pf, parietal foramen; *sm*, stylomastoid foramen; *tyh*, point of articulation of the hyoid arch; *oc*, occipital condyle; *pgp*, postglenoid process; *agp*, anterior glenoid process.



EXPLANATION OF PLATE III.

Skull of *Dromocyon vorax* Marsh; posterior view; three-fourths natural size. (Type.)

ns, nuchal spine; *po*, postorbital process; *pop*, paroccipital process; *fm*, foramen magnum; *oc*, occipital condyle; *smf*, stylomastoid foramen.



EXPLANATION OF PLATE IV.

Under view of the skull of *Dromocyon vorax* Marsh; one-half natural size. (Type.)

apf, anterior palatine foramen; *ppf*, posterior palatine foramen; *mt*, masseteric tubercle; *as*, alisphenoid canal; *fo*, foramen ovale; *flm*. foramen lacerum medius; *gf*, glenoid fossa; *eam*, external auditory meatus; *m*, mastoid; *pp*, paroccipital process; *flp*, foramen lacerum posterius; *oc*, occipital condyle; *cf*, condyloid foramen; *ty*, tympanic; *frm*, foramen rotundum; *sf*, sphenoidal fissure; *op*, optic foramen.

ART. XXXI.—*A new Crinoid from the Hamilton of Charlestown, Indiana;* by ELVIRA WOOD. With Plate V.

THE following paper was prepared in the laboratory of the Geological Department of the Massachusetts Institute of Technology: the specimen having been furnished for study through the courtesy of that institution. I take pleasure also in expressing my indebtedness to Prof. William H. Niles, head of the Geological Department, for the opportunity thus offered.

The specimen which serves as the type of the species described below, although deprived of the free arms and the column, is exceptionally well preserved, showing the more delicate structural features of the test. It is now in the collection of the Massachusetts Institute of Technology.

Gennæocrinus carinatus, sp. nov.

Calyx sub-globose. Arm regions prominent with deep furrows between them. Surface ornamented by delicate, sharply elevated carinæ and acute spines.

Basals three, pentagonal. The five hexagonal radials followed by 2×5 costals. First and second costals slightly, if at all, smaller than the radials. Distichals 1×10. Of the primary palmars immediately following the distichals, that nearest the median line of the ray is an axillary plate bearing 3×20 secondary palmars; the outer is followed by two additional primary palmars, making 1×10 on the inner, and 3×10 on the outer side of the ray, or forty primary palmars in all. Interpalmars three, following one another in vertical succession. The third, or most distal, primary and secondary palmar in each row gives rise to an arm making six arm bases in each ray. The free arms are not preserved. First interbrachial plate followed by two in the second and three in the third row. Plates of the fourth row are variable in number. The succeeding plates merge into those of the tegmen.

The heptagonal primary anal of the posterior area is succeeded by three plates and these by four with a minute triangular plate intercalated between the two rows. Beyond this the plates are irregular in shape and difficult to distinguish, but there are probably five plates in the fourth and three in the fifth row, as represented in the diagram (fig. 1).

Tegmen moderately elevated, made up of small irregularly arranged plates. Ambulacral regions convex and separated by deep sulci extending half way to the summit of the tegmen. Just in front of the arms in line with the center of the ray is a strong spine 3 to 4^{mm} long. Immediately surrounding this

spine is a variable number of plates which bear low spines or nodes. Other plates of the tegmen appear to have been smooth. Anus located half way between the summit and the periphery, its plates not preserved.

Base of the calyx flat, a feature due to a thickening of the basals. This thickening extends over about two-thirds of the surface of each basal and is produced in a thin rim whose margin is parallel with that of the plate.

1

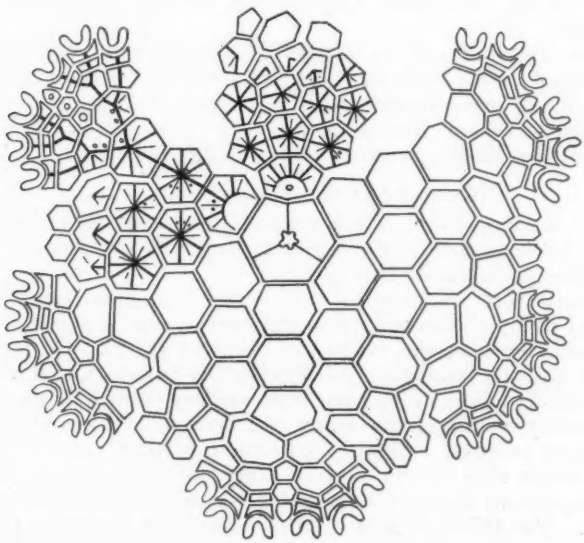


Diagram to show arrangement of calyx plates of *Gennæocrinus carinatus*, sp. nov.

The lower half of each radial and the primary anal plate are ornamented by a projecting crescentic ridge thickened at the center and dying out or terminated by a spine at the sides. From the outer curve of this ridge carinæ pass to the upper sides and angles of the radial, where they meet similar carinæ of the higher brachials. The brachials and interbrachials bear strong carinæ which pass from the center to each side of the plate, and others, less prominent, directed toward but not reaching the angles.

Column circular, occupying one-half the area of the basals. Axial canal pentalobate and having a diameter one-third that of the column.

Observations.—This species is remarkable for its elaborate and delicate surface ornamentation, the thin carinæ rising at right angles to the surface and sometimes a millimeter or more in height.

The whorl of crescentic ridges on the radials when viewed from below bears some resemblance to a six-petaled flower. Each of three alternate petals has a small erect spine at the center.

The carina following the median line of the ray and its branches is stronger than the others and increases in prominence from the radials to the arm bases. This carina is straight to a point above the middle of the second costal, where it divides, each branch crossing a distichal and branching again below the upper angle of the plate. A third branching takes place on the inner primary palmar.

Spines are an important feature of the surface ornamentation. In addition to those already mentioned there are often minute spines in the angle formed by the finer and coarser carinæ of the brachials and interbrachials. These are sometimes elongated, showing a tendency to form a new carina in this position. The second costal bears a very small spine in the angle formed by the branching of the strong carina, and two similar spines are present on the inner side of the distichal below the branching and in line with the straight portion of the carina. Three much larger spines, decreasing in size upward, are present on the interpalmars, one at the center of each plate.

The upper plates of the calyx are somewhat variable in shape. The second costals of the postero-lateral rays are heptagonal, those of the antero-lateral rays pentagonal and the anterior second costal is hexagonal, having three edges on one side, above the base, and two on the other; that is, one represents the heptagonal and the other the pentagonal type of plate. The distichals also vary in shape in the different rays. Those resting upon heptagonal costals have six and those on pentagonal costals seven sides. The distichal on one side of the anterior ray is thus heptagonal and that on the other side hexagonal, corresponding with the irregularity of the adjacent costal. The primary palmars resting upon the distichals are heptagonal on the inner and pentagonal on the outer side of the ray. The first interpalmar is an inverted pentagonal plate, the second hexagonal and the third obscurely pentagonal.

The first interbrachial is in each case regularly hexagonal, but the interbrachials of the second row are six or seven-sided according to the heptagonal or pentagonal shape of the adjoining second costal. The middle plate of the third row is hexagonal, wider at the lower than at the upper end. The other two plates of this row are hexagonal when the nearest distichal has the same number of sides and five-sided when the latter is a heptagonal plate.

The plates of the posterior area are irregular in shape and have five, six, or seven sides. Of the three plates resting upon the primary anal two are hexagonal and one pentagonal.

The plates of the tegmen do not vary greatly in size, the orals being only slightly larger than the others.

Formation and locality.—This species is found in limestones of the Hamilton Group at Charlestown, Indiana.

The species here described is closely related to *Actinocrinus* (*Gennæocrinus*) *cornigerus* Lyon and Casseday, but it differs from the latter in the presence of three instead of two interpalmars, the absence of a central spine on the tegmen and of crescentic ridges on the radials. According to the original description of *G. cornigerus* the plates of the posterior area resemble those of the Actinocrinidæ, that is one hexagonal primary anal followed by two plates; but this species is regarded by Wachsmuth and Springer as synonymous with *G. kentuckiensis*, in which the primary anal is heptagonal and bears three plates as in *G. carinatus*. *G. kentuckiensis* differs from the latter species in the number of distichals which is 2×10 instead of 1×10, and in the arrangement of the palmars and interpalmars the axillary distichals supporting 2×4 palmars in each ray, and the three interpalmars being in two rows instead of one. From both *G. kentuckiensis* and *G. eucharis* the present species differs in the nearly equal size of second costals and radials, in the number and arrangement of the higher plates of the posterior area, and in several other important respects.

Actinocrinus asper Lyon bears an angular ridge on the lower portion of the radials which under favorable conditions of preservation might resemble the petal-like ornamentation of the radials in *Gennæocrinus carinatus*, but the basal plates are not thickened as in the latter species, the costals are very small in comparison with the radials, and each plate of the tegmen bears a strong node.

Gennæocrinus carinatus appears, therefore, to possess an association of well marked and peculiar features which entitle it to be considered a distinct species.

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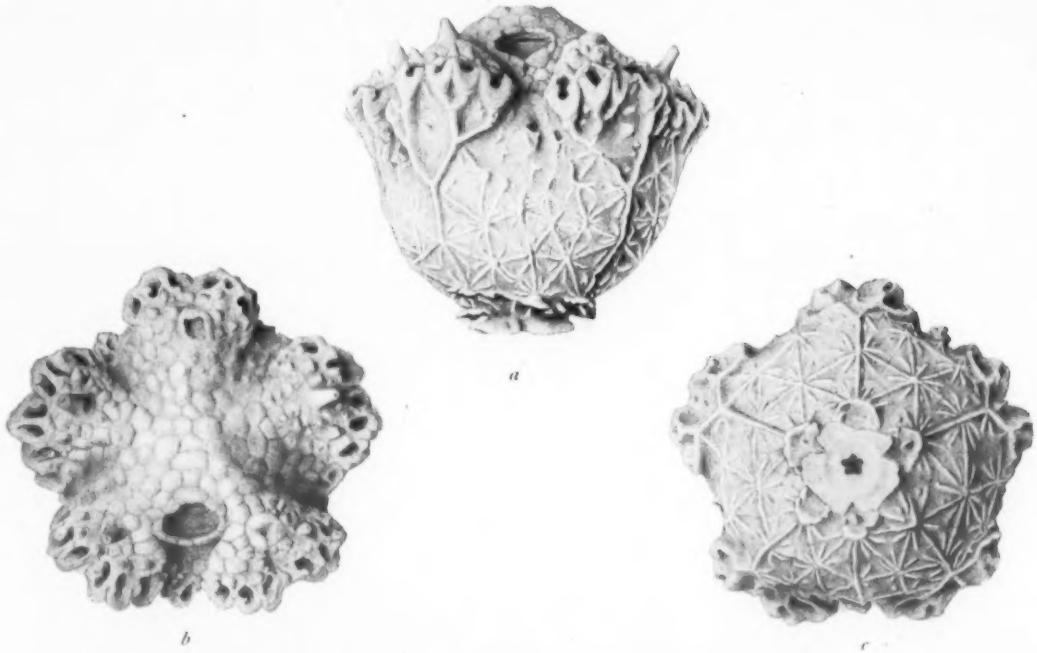

a

b

c

ELVIRA WOOD DEL.

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GENNÆOCRINUS CARINATUS.

a POSTERIOR SIDE. *b* VENTRAL DISK. *c* DORSAL VIEW.

ART. XXXII.—*On the Estimation of Cæsium and Rubidium as the Acid Sulphates, and of Potassium and Sodium as the Pyrosulphates;* by PHILIP E. BROWNING.

[Contributions from the Kent Chemical Laboratory of Yale University—CII.]

BUNSEN* is authority for the statement that the acid sulphate of rubidium does not lose sulphuric acid at a heat approaching redness. It is stated† in the literature that the acid sulphates of cæsium and rubidium when subjected to a low red heat pass into the form of the pyrosulphates. R. Weber‡ found that by treating the dry sulphates of potassium, cæsium, rubidium and thallium with sulphuric anhydride in a closed tube and heating on a water bath two layers separated. In the lower layer he obtained crystalline bodies which proved to have the constitution $R_2O \cdot 8SO_3$. On strong heating he obtained from these substances bodies of the form $R_2O \cdot 2SO_3$ and finally $R_2O \cdot SO_3$. He also notes that in the case of the cæsium salt the removal of the excess of sulphuric anhydride was attended with greater difficulty.

Baum§ states that the pyrosulphates of the alkalies may be obtained by heating the acid sulphates under atmospheric pressure at low redness, or under diminished pressure at a temperature between 260–320° C.

In a recent paper‖ from this laboratory I have shown that thallium may be estimated as the acid sulphate by evaporating a thallous salt in solution with an excess of sulphuric acid and bringing the residue to a constant weight at a temperature of about 250° C. The similarity which thallium bears in some of its combinations to the alkaline metals suggested the study of the sulphates of these elements under the same general conditions of procedure.

My first experiments were made with a pure cæsium salt as follows: A weighed amount of the nitrate was placed in a previously weighed platinum crucible and treated with an excess of sulphuric acid. The crucible was then placed upon a steam bath until the water and nitric acid were largely expelled and then removed to a radiator, consisting of a porcelain crucible fitted with a pipe-stem triangle so arranged that the bottom of the platinum crucible would be about midway between the top and bottom of the porcelain crucible. This improvised radiator was set in an iron ring and a thermometer placed so that the mercury bulb would be on a level with the

* Ann. Chem. (Liebig), cxix, 110.
† Graham. Otto Lehrbuch d. Chem., iii, 278, 269.
‡ Ber. Dtsch. Chem. Ges., xvii, 2497.
§ Ber. Dtsch. Chem Ges., xx, 752. ‖ This Journal, ix, 137, 1900.

bottom and close to the side of the platinum crucible. An ordinary Bunsen burner served as the source of heat and the temperature was kept so far as possible between 250° C. and 270° C. After the fuming attending the removal of the large excess of sulphuric acid ceased, the crucible and contents were removed to a desiccator, and after being allowed to cool, weighed. This process of heating was continued for half-hour periods until the weights were constant. The results shown in Table I were obtained by this method of treatment. In experiments (1), (4) and (9) it will be noticed that the weights were constant somewhat above the conditions of the acid sulphate, a fact which would go to show a tendency on the part of the cæsium salt to hold an excess of sulphuric acid over the amount necessary to form the ordinary acid sulphate. The results show that by regulating the heat at a temperature

Table I.

	$CsNO_3$ taken. grm.	$CsHSO_4$ calculated. grm.	1st constant weight. grm.	2d constant weight. grm.	Error on $CsHSO_4$. grm.	Cs_2SO_4 calculated. grm.	Cs_2SO_4 found. grm.	Error on Cs_2SO_4. grm.
1	0·1706	0·2013	0·2054	0·2020	0·0007 +			
2	0·1706	0·2013	0·2010		0·0003 —			
3	0·1032	0·1217	0·1201		0·0016 —			
4	0·1032	0·1217	0·1252	0·1222	0·0005 +	0·0961	0·0948	0·0013 —
5	0·1218	0·1437	0·1458		0·0021 +	0·1130	0·1118	0·00 —
6	0·1214	0·1435	0·1430		0·0005 —			
7	0·1214	0·1435	0·1422		0·0013 —			
8	0·1150	0·1356	0·1330		0·0026 —			
9	0·1056	0·1245	0·1272	0·1248	0·0003 +			
10	0·1056	0·1245	0·1252		0·0007 +			

between 250° C. and 270° C. cæsium may be brought with a fair degree of certainty to the condition of the acid sulphate. As a check upon the results the acid sulphate was, in a few cases, treated with a little ammonium hydroxide, the excess of this was removed upon a steam bath and the neutral sulphate was obtained by ignition at a red heat to a constant weight. These determinations agreed fairly well with the theory.

The same procedure was followed with rubidium, a pure rubidium chloride having been chosen as the starting point. The results are given in Table II. No tendency was observed on the part of this element to hold sulphuric acid in excess of the amount necessary for the formation of the acid sulphate. When the same method of treatment was applied to the sodium and potassium salts, pure chlorides being used as the starting point, a somewhat different result was obtained, in that the weight of the final product appeared to indicate the formation of the pyrosulphate.

The results given in Tables III and IV, in which the sodium and potassium salts are calculated as pyrosulphates, are sufficiently satisfactory for purposes of quantitative estimation.

As in the case of the cæsium and rubidium salts, a number of determinations as the neutral sulphates were made by ignition of the sodium and potassium pyrosulphates with results which are recorded. In Table V two determinations are recorded, in one of which the cæsium and rubidium salts were treated together, and in the other the sodium and potassium salts. An application of this same general method

TABLE II.

	RbCl taken. grm.	$RbHSO_4$ calculated. grm.	$RbHSO_4$ found. grm.	Error. grm.	Rb_2SO_4 calculated. grm.	Rb_2SO_4 found. grm.	Error. grm.
1	0·1252	0·1889	0·1878	0·0011 —			
2	0·1212	0·1829	0·1840	0·0011 +	0·1460	0·1460	0·0000 ±
3	0·1230	0·1856	0·1850	0·0006 —			
4	0·1230	0·1856	0·1858	0·0002 +	0·1357	0·1350	0·0007 —
5	0·1610	0·2430	0·2416	0·0014 —	0·1777	0·1772	0·0005 —
6	0·1360	0·2052	0·2032	0·0020 —	0·1501	0·1490	0·0011 —

TABLE III.

	KCl taken. grm.	$K_2S_2O_7$ calculated. grm.	$K_2S_2O_7$ found grm.	Error. grm.	K_2SO_4 calculated. grm.	K_2SO_4 found. grm.	Error. grm.
1	0·2172	0·3704	0·3698	0·0006 —			
2	0·1766	0·2909	0·2886	0·0023 —	0·1993	0·1972	0·0021 —
3	0·1192	0·2032	0·2022	0·0010 —	0·1393	0·1381	0·0012 —
4	0·1074	0·1830	0·1823	0·0007 —			
5	0·1096	0·1868	0·1860	0·0008 —			

to a lithium salt gave no evidence of the existence of a stable acid sulphate or pyrosulphate. The results may be summed up as follows: Cæsium and rubidium salts of volatile acids when treated with sulphuric acid in excess and brought to a constant weight at a temperature between 250° C. and 270° C. form acid salts of the type $RHSO_4$ and the neutral salts of the type R_2SO_4 on ignition. Some tendency of the cæsium salt to hold more sulphuric acid than corresponds to the formation of the acid sulphate $RHSO_4$ was apparent at temperatures between 250° C. and 270° C., but upon raising the temperatures above 300° C. the loss was excessive and showed a tendency on the part of the acid sulphate, at this temperature, to pass toward the condition of the pyrosulphate. Sodium and potassium salts when heated under the conditions described give pyrosulphates of the type $R_2S_2O_7$ which on ignition go into the neutral

sulphates of the form R_2SO_4. Lithium gives neither salts of the type $RHSO_4$ nor of the type $R_2S_2O_7$ under the conditions of these experiments.

TABLE IV.

	NaCl taken. grm.	$Na_2S_2O_7$ calculated. grm.	$Na_2S_2O_7$ found. grm.	Error. grm.	Na_2SO_4 calculated. grm.	Na_2SO_4 found. grm.	Error. grm.
1	0·1042	0·1978	0·1972	0·0006—	0·1236	0·1254	0·0012—
2	0·1028	0·1952	0·1952	0·0000			
3	0·1093	0·2075	0·2065	0·0010—	0·1328	0·1320	0·0008—
4	0·1402	0·2662	0·2651	0·0011—	0·1703	0·1696	0·0007—

TABLE V.

	$RbCl + CsNO_3$ taken. grm.	$RbHSO_4 + CsHSO_4$ calculated. grm.	$RbHSO_4 + CsHSO_4$ found. grm.	Error. grm.	$Rb_2SO_4 + Cs_2SO_4$ calculated. grm.	$Rb_2SO_4 + Cs_2SO_4$ found. grm.	Error. grm.
RbCl	0·1428						
(1) $CsNO_3$	0·1264	0·3646	0·3666	0·0020+	0·2749	0·2752	0·0003+
	NaCl + KCl taken. grm.	$Na_2S_2O_7 + K_2S_2O_7$ calculated. grm.	$Na_2S_2O_7 + K_2S_2O_7$ found. grm.	Error. grm.	$Na_2SO_4 + K_2SO_4$ calculated. grm.	$Na_2SO_4 + K_2SO_4$ found. grm.	Error. grm.
NaCl	0·1233						
(2) KCl	0·1340	0·4627	0·4630	0·0003+	0·3062	0·3040	0·0022—

March, 1901.

Art. XXXIII.—*Time Values of Provincial Carboniferous Terranes;* by Charles R. Keyes.

There have recently* been discussed at length certain remarkable features relating to the development of the Carboniferous rocks in the province of the Mississippi valley. The enormous thickness of the Carboniferous of the region—probably upwards of 25,000 feet—and the nicety with which it is separable into serial and minor subdivisions tend to make the general geological section of the Continental Interior basin the standard one for America.

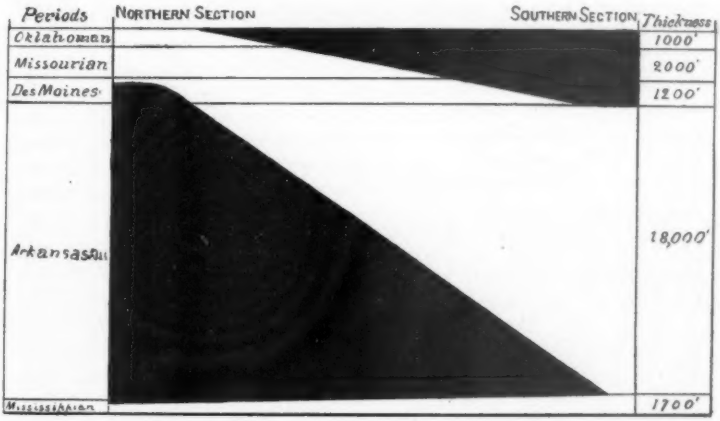


Fig. 1.—Relative Formational Development of the Carboniferous.

In describing the various peculiarities of the formations only the stratigraphical relations and features were considered. The importance attached to the marked inequalities in the development of the five series recognized which was made such a prominent factor and the absence of all reference to the relations of the several series to the time standard, appears to have led to the inference that the time ratios were to be regarded as approximately proportional. It was not the intent to unduly emphasize the stratigraphical disparities at the expense of the time representatives. The latter, for reasons not necessary to specify in detail here, were simply thought to be phases of the subject not to be considered in the article mentioned.

* Bull. Geol. Soc. America, vol. xii, 1901, pp. 173–196.

The stratigraphical features considered are summed up in the diagram above. It represents a meridional ideal section across the Carboniferous basin of the Western Interior region. The north and south ends are drawn to scale. The white represents the relative formational development; and the black the portions now missing.

The very unequal development of the several series has given rise to a tendency to misconstrue the taxonomic ranks of the formations. For example, the Des Moines series has been sometimes given a rank subordinate to that of series; while in the case of the Oklahoman the suggestion has been made to have its rank that of a system.

If the stratigraphical values of the series be represented according to their relative developments, they appear about as follows:

Cimarron	1
Oklahoman	2
Missourian	4
Des Moines	1
Arkansan	35
Mississippian	5

In the general geological scheme, which is dual in character, the time ratios are as important as those represented by the stratigraphy. Faunal and floral comparisons of the different sections are not possible at this time because exact information is scant. We have, therefore, to rely upon data derived from all the available sources. Assuming that the time occupied in the formation of the Des Moines series, according to the corrected valuation hereafter considered, as unity, the factors tending to modify the accepted values indicated by the thickness of the several series may be briefly enumerated.

The Mississippian series is predominently a limestone formation. Taken alone, its lithological composition would indicate a long time element. As a matter of fact, its formation was probably much more rapid than is usual among limestones. The major member is made up of a crinoidal and shell breccia. The accumulation of its material would thus take place many times faster than the formation of fine-grained, non-fossiliferous beds through ordinary precipitation. Another feature indicating that the period during which the Mississippian beds were laid down was not so long as might appear at first glance, is the undoubted oscillation of the sea-floor, which grew quite marked towards the close of the period. In these changes of elevation the uprisings at length predominated over the downsinkings, finally resulting in the complete emergence of a large part of the province above sea-level, and closing the Mississip-

pian period. Over the entire area now known as the Upper Mississippi valley a prolonged period of subaerial erosion took the place of sedimentation. West of the line now occupied by Mississippi river the land border extended southward beyond the latitude of the present Missouri-Arkansas boundary, as lately clearly shown by Marbut.* The full significance of this position of the old shore-line at the close of the Lower Carboniferous is considered elsewhere.† Taken in all its various aspects, the data at hand indicate that the length of time occupied in the formation of the Mississippian was but little more than that during which the Des Moines series was laid down. Compared with the Des Moines, the Mississippian should probably be placed at about one and one-half.

The enormous development of Coal-measures in central Arkansas has been an anomaly in the stratigraphy of the Carboniferous. The thickness, estimated by Branner‡ to be over 20,000 feet, is much greater than that of the entire Carboniferous elsewhere on the American continent. The conditions permitting this vast accumulation were certainly very local and unusual. They are briefly stated§ as follows: South of the latitude of the Boston mountains in northern Arkansas, Carboniferous sedimentation continued on without interruption from the Mississippian; while in the north erosion took place. The sediments from the northern land area, where erosion was going on vigorously, were carried southward and dumped off the shore, rapidly building the latter outward.

There may have been a great land area in northern Louisiana, and probably was. If so, what is now the Arkansas River valley was a broad deep estuary opening out to the west, and the sediments came in from both sides, as well as from the head towards the east. The conditions were then similar to those presented now by the lower Mississippi plain. Only the great embayment opened to the west instead of to the south.

The present Arkansas valley, however, has probably been formed through erosion largely, if not entirely, since Tertiary times and by a system of drainage in no way dependent upon the Carboniferous drainage. When the great uplift of Missouri and Arkansas rose, the northern part, embracing the so-called Ozark isle, and the southern portion, comprising the Ouachita mountains, were made up of resistant limestones, and yielded less quickly to erosion than the central soft shales; and the Arkansas river, which happened, in the old peneplain, to traverse the central part of the uplifted area, was able to main-

* Missouri Geol. Sur., vol. x, 1896, p. 83.
† Bull. Geol. Soc. America, vol. xii, 1901, p. 173.
‡ This Journal (4), vol. ii, 1896, p. 235.
§ Bull. Geol. Soc. America, vol. xii, 1901, p. 195.

tain its old course. The present uplift, which is due to one general movement, is now apparently divided into two elevated regions separated by a broad valley.

While in the south there is this prodigious record of the strata, in the north there is no record at all in sediments. The period of erosion is represented by only a thin irregular plane of unconformity from which alone no time value can be determined. In spite of the enormous thickness of the Arkansan, the time element must have been very much less than would ordinarily be inferred from the figures relating to the vertical interval occupied. The period might have been as extended as the Mississippian; but, all things considered, it would seem much more likely that it was actually considerably more limited than that of the series immediately below. Probably the time ratio would be very nearly the same as for the Des Moines.

Although the Des Moines series is so thin over such a large part of the area occupied by it, it is actually very much more important as a terrane than its relative thickness would indicate. North of the Boston mountains the formation is perhaps nowhere over 500 feet in thickness. The beds composing the series were laid down along a shore which was on the whole gradually sinking.* Many oscillations permitted subaerial erosion to take place time and again, so that the newly formed sediments were frequently removed or worked over almost as fast as they were formed. It was a period when erosion contended against deposition for supremacy, with a result of one making advances at one time and the other at another. The net result was finally a slight gain for sedimentation.† The period was manifestly a long one, for it is believed that in Arkansas no less than 3,500 feet of strata are referable to it. Its time ratio is certainly not very much less than that of the Mississippian.

The Missourian series is essentially a marine formation intercalated between two terranes which were laid down in shallow waters. Its limestones are nowhere the coarse-grained breccias such as occur so frequently in the Mississippian. They are fine-grained and often earthy, and are separated from each other by important beds of shale, which are moreover usually much thicker, reaching measurements of often several hundreds of feet.‡ It is not improbable that part of these beds were laid down while some of the nearer shore sediments of the Des Moines series were being carried into still waters.§

* Iowa Geol. Sur., vol. ii, 1894, p. 113.
† This Journal (3), vol. xli, 1891, p. 273.
‡ American Geologist, vol. xxiii, 1899, p. 298.
§ Iowa Geol. Sur., vol. ii, 1894, p. 162.

In point of the time taken for its formation, the Missourian series may be regarding as ranking with the Mississippian.

The so-called Permian of the Western Interior basin (Oklahoman and Cimarron, the latter generally known as the Red Beds) is composed largely of shales and shaly sandstones. Unusual conditions prevailed during the formation of these beds. In the main, the deposits indicate the presence of shallow waters, in strong contrast to the marine conditions which prevailed previously in the same region. The sediments were laid down largely in more or less closed basins, which may have often had access to the sea, but which finally became altogether dry.

The conditions existing were identical with those under which the original Permian beds of Russia were formed.* Nothwithstanding the comparatively great development of the beds of these series, the formation of them was evidently rapid. The time occupied was probably not more than twice as long as that of the Missourian.

Careful comparison of all available data indicates that the actual time ratios for all the series is very nearly equal. All things considered, this appears quite remarkable. The values seem best to accord with the following figures:

Cimarron	1
Oklahoman	1
Missourian	1½
Des Moines	1
Arkansan	1
Mississippian	1½

* Journal Geology, vol. vii, 1899, p. 320.

ART. XXXIV.—*The Spectra of Hydrogen and some of its Compounds;* by JOHN TROWBRIDGE. (With Plate VI.)

IN a late paper I expressed the conviction that the so-called line spectrum of hydrogen cannot be considered apart from the spectrum of water vapor; and that one can never be sure that one is observing with a condenser discharge a pure spectrum of hydrogen. I am convinced from further experimentation that this conclusion is correct; and I am also led to the conclusion that a certain amount of water vapor is essential in all electrical discharges through gases. Just as aqueous vapor seems to play an important role in most chemical reactions, so, it seems to me, its presence in rarified gases contained in ordinary glass tubes, enables a dissociation to take place which determines the strength and character of the electrical discharges.

I am led, moreover, to the conclusion that pure hydrogen is a perfect insulator, and that the passage of electricity through a gas depends upon the dissociation of the hydrogen and oxygen, by means of which change in the distribution of energy the gases are made luminous. Before proceeding to an account of my experiments, I will state some of the grounds upon which I base my belief that pure hydrogen is an insulator of electricity.

V. Schumann, in an important paper,* has shown that a column of pure hydrogen at atmospheric pressure transmits the ultra-violet rays as well as the most perfect vacuum he has been able to obtain. Now Maxwell's electromagnetic theory of light demands that the space between us and the sun, or in other words the vacuum of space, should be a perfect insulator, otherwise the electromagnetic waves would be completely absorbed and the earth would remain in darkness. This observation of Schumann seems to me one of the most important in physical science, for it proves, I believe incontestably, that hydrogen cannot be a conductor.

Professor Dewar has also shown that liquid hydrogen is an insulator. The experiment sometimes shown, in which a wire, rendered incandescent by a current of electricity and surrounded by an atmosphere of carbonic dioxide, is suddenly diminished in brilliancy by supplanting this atmosphere by one of hydrogen, can be explained, in my opinion, not by the better conductibility of hydrogen for heat, but by the increased resistance of platinum due to the occlusion of this gas by platinum. A

* Ann. d. Physik, No. 3, 1901, p. 642; this Journal, May, 1901, p. 394.

palladium wire increases often as much as fifty per cent. by the occlusion of hydrogen.

The increased length of the electric spark in an atmosphere of hydrogen is not due to an increased conductibility, but to a dissociation of water vapor which is analogous to that which takes place in a voltaic cell.

These are some of the facts which lead me to believe that hydrogen is an insulator and that the water vapor, therefore, plays a controlling part in the passage of electricity through gases. I am conscious that the conclusions in this paper are somewhat radical; and I have, therefore, worked assiduously, during the past three years, to test them in every way which my mind suggested, for it is not probable that many investigators have at present twenty thousand storage cells, which would enable them to repeat my experiments. The strength of currents and the voltage I have employed have certainly reached the limits of glass tubes to withstand such powerful discharges. The form of tube figured in my previous article* is the only one which I have found capable of withstanding steady currents of one-tenth to one-fifth of an ampere, and instantaneous condenser discharges of many hundred amperes.

The great advantage of the use of a storage battery over the employment of a Ruhmkorf coil, in the study of the ionization and molinization of gases, is now generally recognized. This advantage is forcibly seen in the first experiment which I shall bring forward in support of my view of the importance of the rôle played by water vapor in the passage of electricity through gases. A wide tube of the type I have referred to, the narrow portion being approximately one centimeter, was provided with massive copper-ring electrodes, one inch in outside diameter and one-eighth of an inch thick, which were heavily electroplated with copper in order to avoid the impurities of commercial copper. The glass tubes were then exhausted and filled with hydrogen made by the electrolysis of distilled water and phosphoric pentoxide. The gas was sent through tubes filled with caustic potash and many drying tubes filled with phosphoric pentoxide. The gas was kept in the drying tubes many hours; and its flow was delayed by partitions of glass wool. More than a litre of the gas was used in the process of flushing out the spectrum tubes; so that the entire pump and connecting tubes were for several hours presumably filled with hydrogen gas.

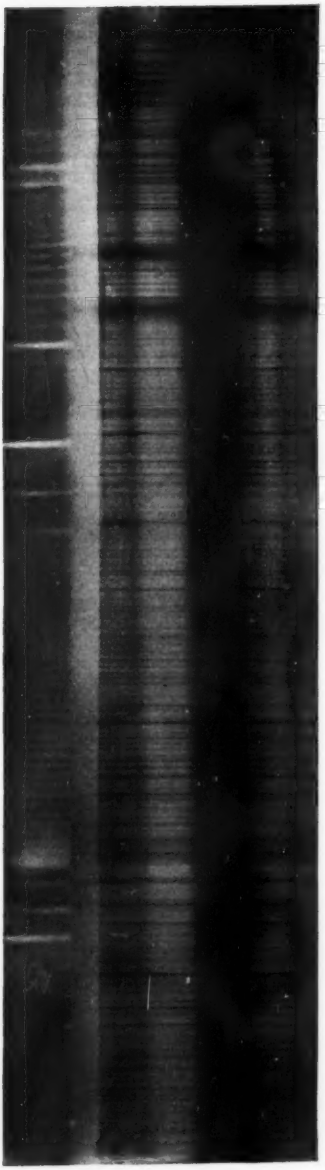
When the tubes, having been exhausted to the most luminous stage, were excited by a condenser discharge and were examined by a straight-vision spectroscope, the ordinary four-

* This Journal, x, 222, 1900.

line spectrum of hydrogen alone seemed to be present. When, however, the invisible portion in the violet was photographed, the bands at wave lengths 3900 and 4315 were invariably present, unless the tube had been maintained, during the process of filling, to a temperature of more than 350° C. After such a process of heating the spectrum became that represented in Plate VI, fig. 2, while before heating it was that shown in Plate VI, fig. 1. In both plates the normal spectrum is above the gaseous spectra. Further toward the ultra-violet, under all conditions, there were also nitrogen bands. Long heating diminished the strength of these bands. This process of experimentation shows that mere eye inspection of glass tubes filled with rarified gases is generally fallacious; we might conclude from this eye study that the presence alone of the four lines of hydrogen denoted that we had this gas in a pure state; whereas the photography of the invisible portion would show that this was far from the truth.

When the glass tubes filled with rarified hydrogen were submitted to the influence of a steady current of electricity, it was found that perfectly pure copper was deposited in a lustrous state on the glass walls of the tube which surrounded the negative terminal, while an olive-green oxide of copper covered the walls around the positive terminal. The same tube was excited by a Ruhmkorf coil, and no difference could be detected in the deposits around both terminals; they were both rusty green with here and there, it may be, streaks of pure copper. The mirrors produced by a strong steady current at the negative terminal were very lustrous and showed no trace of an oxide of copper. It was evident that the current had dissociated water vapor in the presence of an excess of hydrogen, and had reduced the copper at the negative pole and had set free oxygen at the positive pole, which had, in turn, combined with copper. The rarified gases thus acted like a voltaic cell.

When we examine the photograph of the discharge represented on Plate VI we see an interesting exhibition of ionization and molinization. The hydrocarbon bands at wave length 4315 show a series gradually decreasing in length of waves, while another band beginning at wave length 3900, due probably to water vapor, shows a series increasing in length of waves. It would seem that the carbon in one case endeavored to throw off the hydrogen from the hydrocarbon molecule; and in the other case the hydrogen became loaded with oxygen molecules. This to and fro ionization and molinization continues until the oxide of copper at the positive terminal has taken up a large share of the oxygen of the water vapor present. There is thus a critical point in the tube at which a sudden increase of resist-



1

2

ance takes place. It is possible to exhaust glass tubes to such a degree by the mere passage of a strong steady current that X-rays begin to manifest themselves.

When a similar tube, filled with hydrogen with great care and prepared by long heating at a temperature a little below 500° C., is submitted to electrical discharges, the water vapor bands become far less pronounced; and the hydrocarbon band at wave length 4315 entirely disappears, while the light of the tube greatly diminishes in brilliancy. The hydrocarbon or cyanogen band at wave length 3884 is present in all the tubes I have employed; and with whatever gas is submitted to these strong discharges. Strong heating does not cause it to disappear, and it seems to be due to carbonaceous matter introduced into the tubes in the process of blowing for I cannot trace it to impurities coming from the pump. Professor Hartley, in a late communication in Nature, has called attention to the constant presence of hydrocarbon spectra in Geissler tubes. At a later point in this paper I shall return to a further study of these spectra, due to the combination of hydrogen and nitrogen with carbon. At present I desire to dwell upon the point I wish to make: that all discharges in rarified gases contained in glass vessels are conditioned by the amount of water vapor present; and that a steady current passes through a gas at comparatively low pressure much in the same manner that it does through an electrolyte.

In an article on the production of the X-rays by a steady battery current, I dwelt upon the phenomena presented in highly rarified tubes which represent, to my mind, the dissociation of water vapor; and I will refer again at this point to the phenomena already described. According to this hypothesis the rarified water vapor is dissociated at the surface of the anticathode, which is thus greatly heated; the occluded hydrogen plays a part in this phenomenon.

The behavior of large aluminum electrodes in glass vessels filled with ammonia gas is also an interesting example of the dissociation of water vapor. The gas was obtained by heating ammonium chloride, passing it over freshly slaked lime and through drying tubes filled with phosphoric pentoxide. A sufficient amount of ammonia gas was thus obtained for the purposes of spectrum analysis.

When a large condenser, charged to a difference of potential of twenty thousand volts, was discharged through the rarified ammonia gas—there being practically no self-induction in the circuit, and the main effect, therefore, was due to the pilot discharge—the light of the tube changed from a brilliant white to a rosy red; and eye inspection with a straight-vision spectro-

scope showed only the line spectrum of hydrogen. One would conclude from this inspection alone that there was pure hydrogen in the tube. One might also surmise that the oxygen of the water vapor always present on the walls of the glass vessel had combined with the aluminum terminals, setting free the hydrogen which then carried the current. The pressure, however, in the tube increased, and therefore gas must have come from the aluminum. In the exhaustion of X-ray tubes provided with aluminum cathodes much time and long treatment with condenser discharges is necessary to drive out the gases from this cathode. The principal gas seems, from the experiment with ammonia gas, to be oxygen. The same phenomenon is seen in tubes supplied with magnesium terminals, but to a much less extent. It is not seen when the terminals are of copper, iron, silver, platinum or carbon. This behavior of aluminum toward oxygen is very suggestive in regard to the ready passage of the X-rays through this metal.

I have been unable, with the conditions under which I have worked, namely, the use of very powerful discharges, to obtain the spectra of hydrogen apart from water vapor and hydrocarbons. The study, therefore, of the spectra of hydrogen compels one to carefully study the spectra of the hydrocarbons and that of cyanogen; for I am forced to the conclusion that the combination of hydrogen with oxygen is a controlling factor in all discharges through rarified gases. The following is a preliminary study of some of these compounds, which is added at this stage of my inquiry to illustrate this theory. When various gases are put in tubes provided with carbon electrodes and these tubes are exhausted to a pressure of from one to two millimeters the resultant spectra are very similar. The following gases have been studied in the neighborhood of the great H H lines of the solar spectrum:

Hydrogen
Oxygen
Nitrogen

In the hydrogen tube the only lines that appeared in the region from 4320 to 3200 were:

4268 very intense
3922 faint.

The tube was very thoroughly heated while it was being exhausted. The above mentioned lines do not generally appear with hydrogen in tubes with metallic electrodes; but with a tube with platinum electrodes, filled with hydrogen, and heated for two hours during exhaustion at a temperature of

350° C., the same two lines appeared, and in addition the following very faint lines:

3871
3886

These same four lines also appear in carbon tubes when filled with oxygen. In addition, the following lines are present:

3936
3971
4077

All these lines appear in the nitrogen tube, and in addition:

3883
3876
3868
3856
3849
3841

None of these lines appear in tubes with metallic electrodes filled with nitrogen; and they are therefore not nitrogen lines. All the lines in the nitrogen tube are more intense than those in the oxygen tube, and it is possible that with a longer exposure these additional lines would come out in the oxygen.

To study the effect of the carbon terminals, the following gaseous compounds were put into wide tubes provided with copper terminals and rendered luminous by condenser discharges:

Cyanogen
Carbon monoxide
Carbon dioxide
Acetylene.

Cyanogen was prepared by heating mercuric cyanide and passing the gas over sulphur to remove any traces of mercury vapor. Carbon monoxide was prepared by heating potassium oxalate with concentrated sulphuric acid and passing the gas over potassium hydroxide, and collecting over water. Carbon dioxide was prepared by treating potassium carbonate with dilute sulphuric acid and collecting over water. All of these gases were allowed to remain in contact with pentoxide before introduction into the tubes.

With acetylene, carbon monoxide, and carbon dioxide, condenser discharges being employed, the results appear to be identical with those obtained with hydrogen in the tube with carbon electrodes. With cyanogen the same lines appear; and in addition, the bands which are characteristic of these gases

with continuous currents, which will be described later. In general, with condenser discharges, all these spectra are the same; the differences which occasionally appear may be due to changes in pressure, time of exposure, etc.

The line 4268 in all these cases is by far the most prominent line present in the region studied, and may be taken as characteristic of hydrogen, oxygen, and nitrogen in tubes with carbon terminals, and of gaseous carbon compounds in tubes with metallic terminals. This line does not usually appear in hydrogen in tubes with metallic terminals; occasionally it appears very faintly. It appears, however, very strongly in a tube provided with platinum terminals which is filled with hydrogen and heated for two hours during exhaustion to a temperature of 350° C. The spectrum, in this case, appears to be identical with the spectrum of hydrogen in a tube provided with carbon terminals. Were it not for this fact, it would seem as if this line were due to carbon in some form; but even with this fact, it is possible that there was enough foreign carbonaceous matter present in the platinum tube to produce the result noted.

Eder and Valenta* find, among others, the following lines in the spectrum of an induction coil between carbon terminals:

4268
3921

Apparently these are the same lines found in the tubes provided with carbon electrodes; and also in tubes with metallic electrodes which are filled with carbon compounds. Observed visually, with a straight-vision spectroscope, all the above cases appear identical. When, for instance, hydrogen was put into the tube with carbon terminals and submitted to discharges from an induction coil, at first the line spectrum of hydrogen appeared. After the discharge had passed for some time, this gradually changed into the characteristic band spectrum of carbon. To the eye alone the change was equally noticeable; the light being, at first, reddish, and then changing to a white. Similar changes were noticed when nitrogen and oxygen were used in the carbon tube.

It seems to me that the following conclusions can be drawn provisionally from the above: When various elementary gases are introduced into wide tubes with carbon electrodes and exhausted to a pressure of 1–2^{mm}, and submitted to condenser discharges, compounds of carbon with the various gases are formed. With nitrogen this compound is probably cyanogen; with hydrogen acetylene; but when a photograph of the spectrum in each case is taken, we get, not the spectrum of the

* Beiblätter, xviii, 1894, p. 753.

compound, nor that of the elementary gas, but a carbon spectrum. This, however, does not mean that we get the line spectrum of elementary carbon; for it is certain that there is water vapor present in the tubes, notwithstanding the temperature to which it has been subjected. The carbon may then unite with the oxygen of the water vapor, forming either carbon monoxide or dioxide; the hydrogen being occluded by the terminals or the glass walls.

Just as the spectra of gaseous carbon compounds in wide tubes with metallic terminals appear identical with the spectra of elementary gases in tubes with carbon electrodes submitted to condenser discharges, so we should expect that the spectra produced would be the same in the two cases. This is found to be true. The general appearance of the photographs obtained with continuous currents is very different from those obtained with condenser discharges. In the former case there is a marked band appearance in addition to a line spectrum. The most prominent of these bands in the region studied is the one beginning at 3884. With the dispersion used this band consists of five prominent lines crowding together toward the ultra-violet. A somewhat similar band, apparently of six lines, begins at 4216. Another band, rather faint, consisting of a large number of fine lines shading off toward the ultra-violet, begins at 4126. The bands beginning at 4216 and 4884 appear to be the same as the bands which Kayser and Runge* designate respectively as the second and third cyanogen bands in the arc spectrum of carbon in air.

Besides these bands a number of single lines appear which are common to all the gases. Among these, the most prominent are:

3652
4048
4080
4360

In the tube filled with cyanogen many of the same lines that appear in tubes with metallic terminals filled with nitrogen are present besides the above. This is true to a certain extent of the other gases; and it is not surprising, since it is to be expected that some atmospheric air is always present as an impurity.

The conclusions to be drawn from these experiments with steady currents are similar to those we have deduced from condenser discharges. When elementary gases are introduced into tubes with carbon terminals and exhausted to a pressure

* Abhandlungen der Akademie der Wissensch. zu Berlin, 1889.

of 1–2^{mm}, and are submitted to continuous currents, we obtain the spectrum of carbon or some compound of carbon. From the above results very little information can be obtained as to what this compound is. The same spectrum is obtained whatever gas is introduced into the tube; and moreover, this is the same spectrum which is given by gaseous carbon compounds in tubes with metallic terminals.

What, then, are the conclusions to be drawn from the present stage of this investigation with gases submitted to powerful electric discharges? It seems to me they are as follows:

1. Hydrogen is an insulator.

2. The passage of electricity through hydrogen, nitrogen, oxygen and their gaseous compounds, is conditioned by the water vapor present.

3. The dissociation of this water vapor in the case of tubes filled apparently with pure hydrogen, under the effect of a strong steady current of electricity, shows an electrolytic action closely analogous to that of the voltaic cell. In the case of electrolytic copper terminals in an atmosphere of hydrogen, pure copper is deposited from the negative terminal; and a suboxide of copper at the positive terminal.

4. Under the effect of powerful condenser discharges oxygen is set free from commercial aluminum and magnesium.

5. Certain carbon bands are always present in glass tubes filled with hydrogen, nitrogen, oxygen and ammonia gas notwithstanding the greatest care which may be taken in submitting them, during the process of exhausting, to a high temperature, when powerful discharges are employed.

6. The brilliancy of the light of tubes filled with hydrogen diminishes as the process of the dissociation of water vapor goes on and the resistance of the tube increases. It is possible to raise such a tube to the X-ray stage from a pressure of 1–2^{mm} merely by the application of a strong steady current.

7. The X-rays excited by the application of a steady current are due to the radiations set up by the dissociation of highly rarified water vapor.

Jefferson Physical Laboratory,
Harvard University.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Induced Radio-activity produced by Salts of Radium.*—An interesting series of experiments has been made by P. Curie and A. Debierne, which shows that radio-activity is transmitted in the air through short distances and induces activity in other substances. This induced activity is much more intense when it is produced in completely closed vessels than when the action takes place in the open air. A radiferous substance was placed in a small open bulb in a closed vessel, and plates of various substances (lead, copper, aluminium, glass, ebonite, card, paraffin, all of which appear to be acted on in about the same manner) were placed in various positions in the vessel, and in all positions, even behind a lead screen, they became active to about the same extent after a day's exposure, provided that the air of the vessel had free access to their surfaces. A plate resting on the bottom of the vessel became active only on its exposed surface. With very active barium chloride (radium), plates exposed for several days in this way attained an activity 8000 times greater than a plate of metallic uranium of the same dimensions. When exposed to the free air, the plates lose the greater part of their activity in a day, but the activity disappears much more slowly when the plates are left in the closed vessel after the active substance has been removed. If the experiment is made with the bulb containing the active substance completely closed, no induced activity is obtained. Other experiments showed that this induction is rapidly carried through capillary tubes connecting small closed spaces. It was found that the action is progressive, finally reaching a limit which depends upon the activity of the active body. The action is more rapid the smaller the vessel containing the bodies. These phenomena have been observed with various salts of active barium, such as the chloride, sulphate, and carbonate. Salts of actinium also produce induced activity, but, on the other hand, salts of polonium, even when very active, produce no such effect. The authors believe that this circumstance may have a connection with the fact that polonium does not emit rays that are deviated by the magnetic field.

In a subsequent communication the same authors state that water can be rendered radio-active either by distilling it from a solution of radium chloride in an air-tight vessel, by placing a dish of water in a closed space containing a solution of a radium salt, or also by enclosing a solution of a radium salt in a hermetically closed celluloid capsule and plunging the latter into distilled water in a closed vessel. In the last case, no trace of the salt passes into the water, but the activity of the solution is to a great extent communicated to it. This induced activity can-

not be transmitted by air through a wall of dry celluloid, but it passes easily if the wall is wet with a drop of water. Water can be rendered very strongly active, but when kept in a sealed tube it loses the greater part of its activity in a few days. When kept in an open vessel the water loses its activity much more rapidly, the loss being the more rapid the greater the surface exposed to the air. Solutions of radium salts in open vessels behave in the same way as the water just mentioned, but in this case the loss of activity is not absolute, for if such a solution is put into a sealed tube it gradually acquires its original activity in the course of ten days or so. The authors look upon radio-activity as being analogous to heat in being dissipated by radiation and by conduction. In the latter case it passes through gases and liquids, but not through solids. If a solid radio-active body is left free to the air, its activity does not diminish sensibly, and the authors have shown that a solution of a salt produces much more intense phenomena of induced radio-activity (twenty times greater) than the solid salt itself. When the salt has been in solution several days, the radio-active energy is divided between the salt and the water, and if the latter be then distilled off, it contains a great part of the activity, while the solid salt is much less active (ten or fifteen times, for example) than before solution. When left to itself the solid salt regains, little by little, its original activity. The communication of the activity of a radium salt to its water of solution is very slow, and equilibrium is obtained only after about ten days.—*Comptes Rendus*, cxxxii, No. 9; cxxxiii, No. 5. H. L. W.

2. *A New Method of Quantitative Analysis.*—R. W. THATCHER has devised a method for determining the weights of precipitates without separating them from the liquid from which they are precipitated. The proposed method consists in determining the weight of a measured volume of the precipitate and mother-liquor, and then determining the specific gravity of the mother-liquor alone. From these data, if the specific gravity of the precipitate is known, the weight of the latter may be calculated by the formula,

$$x = \frac{d(a - bd')}{d - d'},$$

where a is the total weight, b the total volume, d the specific gravity of the precipitate, and d' the specific gravity of the liquid. In order to apply the method, the author determined the specific gravities of a number of precipitates by using known quantities of soluble compounds of the substances to be determined, precipitating as usual in this process, and determining the specific gravities of the mixture and of the mother-liquor. A modification of the formula that has been given then served to give the required specific gravities. The analytical operations were carried out by the use of two Geissler specific gravity bottles of 100 and 50^{cc} capacity. A precipitation was first made in

a volume less than that of the larger bottle, the whole was transferred to the latter at a temperature below 20°, which was used as the temperature for weighing, and the bottle was filled with water, the contents thoroughly mixed, and the whole finally weighed. To obtain the mother-liquor free from the precipitate, the contents of the bottle were transferred to a test-tube and whirled in a centrifugal machine. For setting most precipitates less than one minute was required, while in no case was it necessary to spin the apparatus more than three minutes. The clear liquid was then drawn off by means of a dry pipette, and its specific gravity was taken in the smaller Geissler bottle. The author has applied the method to the determination of chlorine as silver chloride, sulphur as barium sulphate, calcium as oxalate, phosphoric acid as ammonium phosphomolybdate and invert sugar by means of the cuprous oxide precipitated, with very satisfactory results. The method requires that the composition of the precipitate should be constant, although it need not be exactly known. It was found that the specific gravity of aluminium hydroxide varies with the time that elapses after precipitation, so that the method is not yet applicable to the determination of this substance. It is expected that the method will find considerable application, particularly for rapid work in technical analysis, but it requires very accurate specific gravity determinations where quantities of about one gram are taken, a circumstance which will probably limit its adoption by analytical chemists.—*Jour. Amer. Chem. Soc.*, xxiii, 644. H. L. W.

3. *Europium, a New Element.*—By a long series of fractionations with magnesium nitrate DEMARÇAY has separated an earth, intermediate between gadolinium and samarium oxides, of sufficient purity to show no samarium lines, and only mere traces of gadolinium lines in the spectrum. The solutions give absorption-bands, and when traces of calcium sulphate are added to the oxide a brilliant phosphorescent spectrum is produced. The approximate atomic weight 151 is mentioned, but no details in regard to the determination, nor any account of the chemical properties of the substance are given. Numerous spectrum lines are described, however, and the name given above is proposed for the element.—*Chem. News*, lxxxiv, 1. H. L. W.

4. *Research Papers from the Kent Chemical Laboratory of Yale University;* edited by FRANK AUSTIN GOOCH, Professor of Chemistry in Yale University. In two volumes: Vol. I, pp. xiv, 411; Vol. II, pp. x, 415. New York, 1901 (Charles Scribner's Sons, price $7.50 net).—This work forms part of the "Yale Bicentennial Publications," a series of volumes prepared by the Professors and Instructors of Yale University and issued in connection with the Bicentennial Anniversary to be held Oct. 20–23 of the present year; the series is designed as "a partial indication of the studies in which the University teachers are engaged."

The Kent Chemical Laboratory established at New Haven

through the liberality of Mr. Albert Emmett Kent, was opened in 1888 under the direction of Professor F. A. Gooch. The original research work accomplished in the laboratory since that time by Professor Gooch and his students is now presented together in these two volumes. One hundred and eight papers are included, the larger part of them upon analytical processes in inorganic chemistry. A critical review of these papers is not called for in this place since almost all of them have been published in the pages of this Journal from vol. xxxix, 1890, to the current volume. This collection of papers speaks most strongly for the large amount of excellent original work which has been accomplished in this laboratory.

5. *Magnetic Effect of Electrical Convection.*—A discussion of the experiments of Rowland and of Cremieu upon this subject is given by H. A. Wilson in the July number (pp. 144–150) of the Philosophical Magazine; the object of the paper being to point out that Cremieu's failure to confirm Rowland's results is to be attributed rather to the methods employed than to the non-existence of these effects. The author's conclusions are stated as follows:

"(1) That in Cremieu's attempt to detect the electrostatic effect of a varying magnetic field, the effect of the steady magnetic field on the charging currents was left out of account, and that his latter effect is equal and opposite to the former.

(2) That, consequently, Cremieu's negative result constitutes an indirect proof of the existence of an electrostatic effect of a varying magnetic field, of the amount usually predicted theoretically.

(3) That in Cremieu's attempt to repeat Rowland's experiment, his addition of a metallic screen placed close up to the fixed sectors should cause a current to be produced which should almost entirely compensate the desired effect.

(4) That Cremieu's partial failure without the additional screen, is quite possibly due to defective insulation of his sectors."

The experiments of H. Pender upon the same subject, briefly stated in the Johns Hopkins University Bulletin No. 152 (this Journal, xii, p. 173), are discussed at length in the August number of the Philosophical Magazine.

6. *The Effect of Amalgamated Gases on Resistance;* by William Rollins. (Communicated.)—As the result of experiments with X-light tubes, I concluded that we depend on gases amalgamated with the terminals of a vacuum tube for an efficient cathode stream for producing X-light. It, therefore, seemed desirable to see if the partial removal of these gases would in any way change the resistance of the metal forming the terminals. Spiral terminals were made, the ends of each spiral being brought to the outside of the tube so that a current could be sent through the spirals before the X-light tube was pumped and after as much gas as possible had been removed from the metal by heat, electricity and pumping. Mr. Oelling and Mr. Heinze constructed

the tubes and made the tests during the summer of 1900. They reported that the resistance of a wire was increased by removing the amalgamated gases. In one experiment the resistance of the wire forming a spiral terminal in an X-light tube was ·068 of an ohm before and ·080 after. The instruments for making the experiments were not of a high grade. On this account the results were not reported, as I hoped to repeat the experiments with better apparatus and with terminals made of all the common metals. As this opportunity has not come, I now report the experiments that some one better equipped may extend them.

II. Miscellaneous Scientific Intelligence.

1. *American Association.*—The fiftieth annual meeting of the American Association for the Advancement of Science was held at Denver, Colorado, during the week beginning August 24th. The President of the meeting was Professor Charles S. Minot of Cambridge. The attendance was larger than might have been anticipated considering the distance of Denver from Eastern centers, the registration reaching 311; nearly one-third of those in attendance came from the Atlantic coast. The interest taken by the citizens in the proceedings and their efforts for the entertainment of the guests contributed essentially to the success of the meeting. About 220 papers were presented for reading at the sessions of the Association and those of the affiliated societies, which were also well attended. The address of the retiring President, Professor R. S. Woodward, was delivered on the evening of August 27 on the subject "The Progress of Science." The address is printed in full in the issue of *Science* for August 30. The following numbers of the same journal, which is now the official organ of the Association, contain a detailed account of the Denver meeting with the addresses of the Vice Presidents before the several sections.

The place selected for the meeting of 1902 is Pittsburg, the meeting to embrace the week from June 28 to July 3. The officers elected are as follows:

President, Asaph Hall.

Vice Presidents: Section A, G. W. Hough, Northwestern University; Section B, W. S. Franklin, Lehigh University; Section C, H. A. Weber, Ohio State University; Section D, J. J. Flather, University of Minnesota; Section E, O. A. Derby, São Paulo, Brazil; Section F, C. C. Nutting, Iowa State University; Section G, D. H. Campbell, Leland Stanford University; Section H, Stewart Culin, University of Pennsylvania; Section I, C. D. Wright, Commissioner of Labor, Washington; Section K, W. H. Welch, Johns Hopkins University.

Permanent Secretary, L. O. Howard of Washington; *General Secretary*, D. T. MacDougal, New York Botanical Gardens; *Treasurer*, R. S. Woodward, Columbia University.

A meeting of the Association will also be held in Washington

during "convocation week," that is the week of Jan. 1st, 1903. This mid-winter meeting is a decided change of policy, but it is left for the future to decide whether the time of meeting shall be permanently changed or whether there shall be two meetings annually.

2. *British Association.*—The meeting of the British Association for the Advancement of Science was held in Glasgow, Sept. 11 to 18. The presidential address was delivered by Prof. A. W. Rücker (see Nature, Sept. 12).

3. *Catalogue of the African Plants collected by Dr. Friedrich Welwitsch in 1853–61. Vol. II, Part II, Cryptogamia*, British Museum (Natural History), 1901. Pp. 261–565.—The final portion of this work is especially valuable since it contains accounts by no less than ten specialists of all the divisions of cryptogams from a region where the lower plants had been seldom collected. The groups most fully treated are the fresh water algæ by W. & G. S. West and the lichens by E. A. Wainio. It is stated that the earliest collections of algæ made in Africa are more extensive and representative than any hitherto described. Of the orders of fresh water algæ the Desmidiaceæ and Myxophycæ are best represented. It is of interest to note the occurrence of *Nostochopsis lobatus* Wood, first discovered in the United States, and later found in South America. In looking over the list of fresh water species from Africa, one finds a confirmation of the fact that fresh water algæ are more cosmopolitan in their range than any other plants except perhaps the algæ of brackish water. The marine algæ which were worked up by Miss E. S. Barton are, as might have been expected, much less numerously represented, only forty species being enumerated, and some of these were collected at Madeira and the Cape Verde Islands. The lichens include a large number of new species which are described in detail. The fungi were determined by Miss A. L. Smith, and include the species of Welwitsch previously described by Curry and Lagerheim. Of the four Mycetozoa enumerated by Arthur Lister, two were first found in the United States. The mosses by Antony Gepp, and the hepatics by F. Stephani include a number of new species, and the vascular cryptogams are given by W. Carruthers with the description of but one new species. There is also a general index of both volumes of the catalogue.

W. G. F.

4. *Leitfaden der Wetterkunde, gemeinverständlich bearbeitet;* von Dr. R. Börnstein. Pp. 181 with 17 plates and numerous text figures. Braunschweig, 1901 (Fr. Vieweg u. Sohn).—The number of those interested in the science of weather predictions and desirous of having an intelligent knowledge of the meteorological principles upon which they are based has increased very largely in recent years in consequence of the admirable work done by the various Government Bureaus. To them, as also indeed to those who have already had a training in this branch of science, the author's concise and systematic treatment of the subject will be of great value. He discusses all the topics

involved with uniform clearness throughout and—so far as space allows—with much thoroughness. At some points the work contains so much that it will call for close study from those not already well grounded in physical science. An interesting chapter is that giving a brief account of the work of the Weather Bureaus of the various governments. The book is well illustrated, the charts at the end including, for example, the representations of the different types of clouds, being particularly good.

5. *Studien über die Narkose;* von DR. E. OVERTON. Pp. 195. Jena, 1901. G. Fischer.—This monograph contains a review and critique of the more prominent theories of the mode of action of narcotics and anaesthetics. The greater part of the book is taken up with a discussion of the theory of narcosis which has recently been advanced by Professor Hans Meyer of Marburg, and advocated independently by the author. Briefly, this theory assumes that all chemically indifferent compounds which are soluble in fats or similar substances act as narcotics on living protoplasm to the extent to which they are distributed therein. This action will obviously be most pronounced on those tissues which are richest in fat-like compounds, viz., the nervous tissues. The comparative efficiency of various substances as narcotics (anaesthetics) must be dependent on their relative affinity for these fat-containing tissues and the tissue fluids respectively. Dr. Overton has attempted to ascertain this relationship—the coëfficient of distribution—for a number of organic compounds which act as narcotics. Many experiments on plants and animals—mostly lower forms—are reported in detail by the author, who is an assistant in botany at the University of Zürich. L. B. M.

6. *Ueber Harmonie und Complication;* von Dr. VICTOR GOLDSCHMIDT. Pp. 136, large 8vo. Berlin, 1901 (Julius Springer).—Starting from some of the fundamental principles of crystallography, the author has attempted to show that analogous laws exist both in the harmonic relations and in their combination in other departments of science—as in sound and light. Thus the so-called harmonic series of numbers of which a simple example is given by $0 \cdot \frac{1}{2} \cdot 1 \cdot 2 \cdot \infty$, which in crystallography defines the position of the planes in a crystal in terms of the molecular forces, is believed to fix the positions of most of the notes of the musical scale and also those of the chief Fraunhofer lines in the solar spectrum. It would be impossible in a brief space to make clear the methods of the author in arriving at this conclusion, still less to explain his manifold deductions. The reader cannot fail to appreciate the industrious ingenuity exercised even if not convinced as to the correctness of all the views advanced.

7. *Nature's Miracles: Familiar Talks on Science;* by ELISHA GRAY, Ph.D., LL.D. Vol. III. Electricity and Magnetism. Pp. 248, 12mo. New York, 1901 (Fords, Howard and Hulbert).—In this little volume the writer presents some of the important topics in electricity and magnetism in simple language and with familiar illustrations, designed to interest the general reader to whom scientific treatises are closed books.

Obituary.

Charles Anthony Schott, for many years a prominent member of the staff of the United States Coast Survey, died on July 31 at the age of seventy-five years. Born at Mannheim, Germany, in 1826, he came to this country at the age of twenty-two and at once entered the service of the United States Coast Survey, in connection with which he was to do such important work. A man of keen, well-trained and original mind, endowed with unlimited energy and industry, his labors, carried on for half a century, have contributed no small part to the grand total accomplished by this Bureau. He was early attached to the Computing Division and in 1855 he assumed charge of this department, a position which he retained until January, 1900; in 1856 he was advanced to the rank of assistant. He is best known for his numerous and important contributions to Terrestrial Magnetism, frequent references to which will be found in these pages. It was in recognition of his services in this direction that in 1898 he received the Wilde Prize from the French Academy. After being relieved of his duties as Chief of the computing division, early in 1900, he was assigned to the discussion of the arc measurements in the United States; the volume entitled "The Transcontinental Triangulation and American Arc of the Parallel" was prepared by him (see this Journal, vol. xi, p. 172, 1901). This important work and another, "The Eastern Oblique Arc of the United States," now about to be issued, form a fitting close to the labors of a long and most useful career.

The following just tribute, adopted Aug. 1 by the members of the Survey, well expresses the estimate of the man formed by those most closely associated with him: "He was enthusiastic, faithful, and diligent in all duties he was called upon to perform, and through his learning and probity earned a reputation extending over two continents which is most worthy of emulation. Conscientious and expert in his specialties, geodesy and terrestrial magnetism, his labors added immeasurably to the reputation of the Bureau and of his comrades who gathered the material he so ably discussed. The methods of computation now in use in the Bureau are an indelible record of his ability. His high ideals of duty and his tireless and persistent striving for them made him stand forth as a noble example of the best type of public official, and his uniform kindliness endeared him to those who knew him as a friend."

Baron Adolf Erik Nordenskiöld died at Stockholm on August 12 in his sixty-ninth year. He was alike renowned for his numerous and important contributions to the Mineralogy and Geology of Scandinavia and even more for his intrepid explorations in the far north.

Dr. Wilhelm Schur, Professor of Astronomy at Göttingen, well known both for his researches and his work as a teacher, died the past summer at the age of fifty-five years.

Baron de Lacaze-Duthiers, the celebrated French zoologist, Professor in the Sorbonne, died on July 21 in his eighty-first year.

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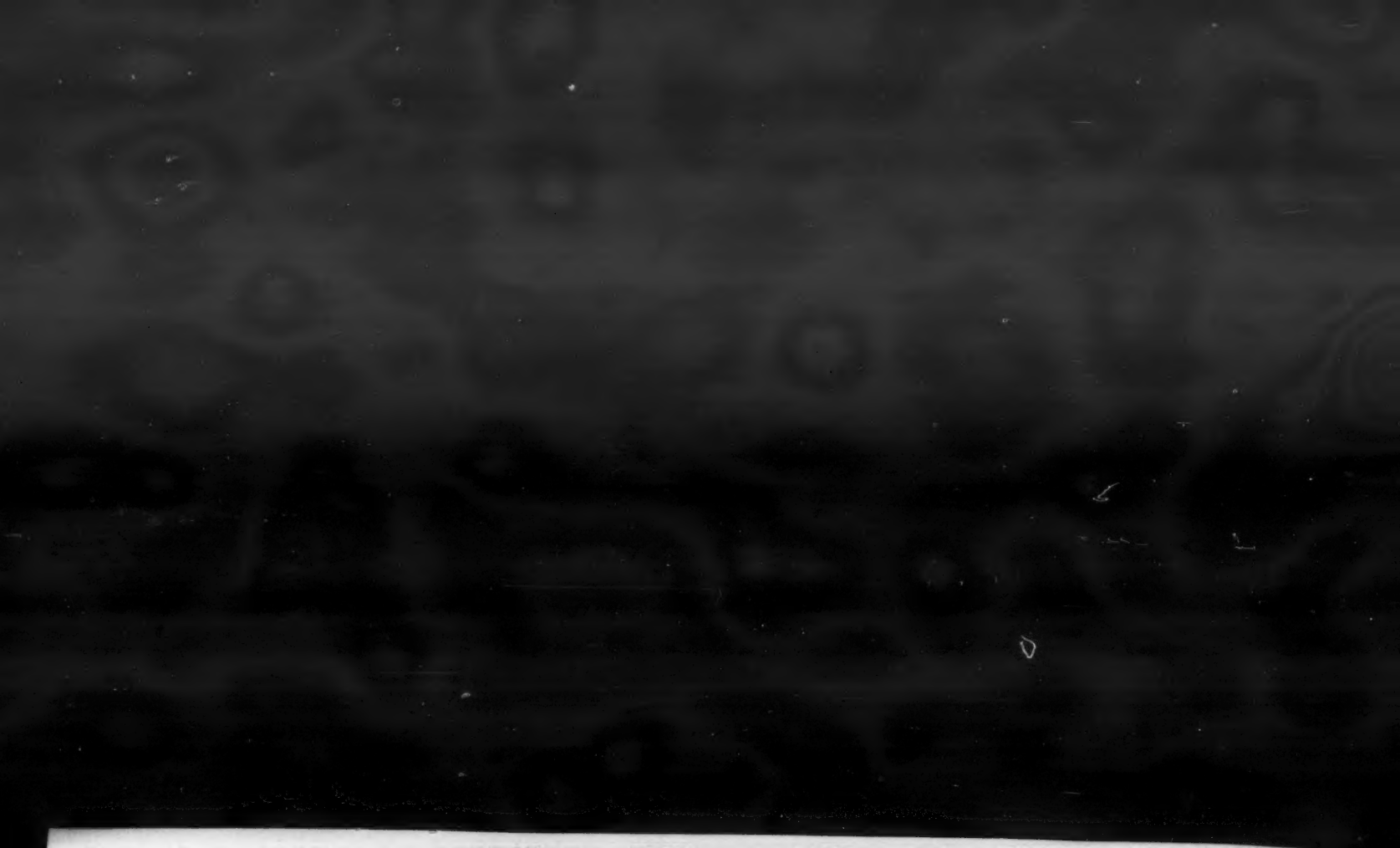
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